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# **TRENDS IN CALIFORNIA BLACK BASS FISHING TOURNAMENTS, 1990–1994, AND COMPARISONS WITH 1985–1989 DATA**

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Reports from California black bass (largemouth bass, *Micropterus salmoides*; smallmouth bass, *M. dolomieu*; and spotted bass, *M. punctulatus*) fishing tournaments from 1990 to 1994 were analyzed to estimate annual angler effort, catch, fish weight and mortality and to detect trends in these variables. A total of 1,425 event tournaments was scheduled and 1,283 reports were received from them. An additional 3,277 annual contests were scheduled and 2,718 reports received. The total number of event and annual contests scheduled increased slightly from 1990 to 1994. Over these years an estimated 1,135,024 hours of fishing effort, representing 123,189 angler-days, were expended to catch 240,263 bass in event tournaments. Total effort and mean weight of bass increased between 1985–1989 and 1990–1994 without an increase in catch per hour. This suggests that, as this is a catch and release fishery, the bass population did not increase, rather many of the same fish must have been caught more than once. Estimates of mean annual catch per hour in event tournaments ranged from 0.184 in 1991 to 0.246 in 1994. Total estimated initial mortality for event tournaments was 2,165 bass from 1990 to 1994 and was highest during late June to August. The number of angler days, the number of black bass caught, the catch per hour, and the mean weight of black bass were significantly higher in 1990–1994 compared to 1985–1989. During the same period, 554,742 hours of fishing effort, representing 60,251 angler days were expended to catch 123,769 bass in annual tournaments. Initial mortality of bass was significantly lower following the 1989 implementation of "Special Conditions" for black bass tournaments. At this time, additional restrictions on black bass tournament angling are not necessary to further protect the fishery.

## **INTRODUCTION**

This is the second 5-year summary of black bass (largemouth bass, *Micropterus salmoides*; smallmouth bass, *M. dolomieu*; and spotted bass, *M. punctulatus*) fishing contest reports for California. Lee et al. (1993) reported on contests conducted from 1985 to 1989. Of the 3 species, largemouth bass are the most commonly caught, followed by spotted bass.

In 1990, the permitting procedure for black bass fishing contests was changed by the California Fish and Game Commission to increase the amount of data gathered from fishing contests. Prior to 1990, only sponsors of contests offering more than



\$200 in prizes and/or inducements were required to obtain a permit. In 1990, regulations were established to provide 2 types of permits, event and annual. The event permit was designed to gather data from and regulate large fishing contests, generally sponsored by commercial organizations. It gathered data from the same kind of organizations that sponsored permitted contests from 1985 to 1989. The annual permit was designed not to regulate, but simply gather information from smaller organized fishing contests, generally local bass clubs or individuals. Prior to this change, small club contests were not required to have a permit and the Department of Fish and Game (CDFG) was unable to gather data from them.

An event permit is required when more than 50 individuals participate in a contest of \$1,000 or more in prizes or inducements is offered. One event permit may be issued per water per species per day, with the exception of the Sacramento-San Joaquin Delta where 2 events are allowed per day. Only 1 contest may be conducted on a single event permit. An annual permit is required when there are 50 or fewer participants and prizes or inducements are less than \$1,000. The number of annual permits is not limited by water, species, or date and up to 12 individual contests can be authorized on an annual permit.

Tournament sponsors generally conduct either a "team" or "draw" type tournament. Team tournaments usually consist of 2 individuals fishing together, as a team, in the same boat. They attempt to amass the heaviest weight for the sponsor's designated limit of bass, not to exceed the state's legal limit for the particular water fished. Designated team limits were generally 5 or 7 fish per boat. When a "team" consists of only 1 individual, this person cannot catch more than the state limit. For a draw tournament, the sponsor matches 2 anglers who then fish in the same boat but as individuals, each attempting to amass the heaviest weight for the designated state limit for the water fished.

Black bass tournaments from 1990 to 1994 continued to be conducted as in 1985 to 1989 (Lee et al. 1993). Competitors were required to comply with all California sport fishing regulations. The general statewide daily bag limit was 5 fish per angler and the minimum size limit was 305 mm total length (TL). Black bass contest sponsors were also required to abide by the "Special Conditions" instituted in 1988 and appended to all black bass contest permits. Special Conditions were: 1) bass transported between the boats and weigh-in site must be held in water-filled containers, 2) the maximum time that bass could be held in the containers was 3 minutes, 3) the number of fish was limited to 5 per container and bass >5 pounds (2.27 kg) had to be held in individual containers, 4) holding tanks had to be near the weigh-in site, 5) the maximum allowable fishing time was 6 hours between weigh-ins for tournaments conducted between 15 June and 15 September, and 6) all black bass were to be returned to the water alive and in good condition.

Sponsors were required to provide reports within 30 days of the contest date. Sponsors who did not return the required report were contacted to retrieve the information, but some sponsors were not reachable and information could not be obtained.

The objectives of this paper were to 1) estimate annual angler effort, catch, fish



size, and fish mortality from 1990–1994, 2) determine if trends in these variables existed from 1985 to 1994, 3) test effectiveness of the special regulations in reducing mortality, and 4) to compare 1985–1989 and 1990–1994 event tournament data (Lee et al. 1993) to elucidate long-term changes in tournament angling. Because annual permits were first implemented in 1990, no comparable annual permit data were available for 1985–1989.

## METHODS

All reports received for event and annual tournaments held in 1990–1994 were included in our analysis and the data summarized (Table 1). The mortalities reported by contest sponsors were initial mortalities, measured as the numbers of dead fish weighed in.

Table 1. Event and annual black bass tournaments data 1990–1994.

<u>Year</u>	Event Contests				Total	Total	Catch	Initial	%
	Cnt's <u>sch'd</u>	Rpts <u>rec'd</u>	Days <u>fished</u>	Angler <u>days</u>					
1990	277	259	251	21,612	204,375	44,409	0.217	531	1.2
1991	265	236	264	20,141	179,239	32,937	0.184	292	0.9
1992	282	249	245	21,881	202,062	39,632	0.196	428	1.1
1993	303	279	295	24,377	227,936	47,212	0.207	310	0.7
1994	298	260	262	23,674	219,132	53,812	0.246	399	0.7
Total	1,425	1,283	1,317	111,685	1,032,744	218,002	0.211	1,960	0.9

<u>Year</u>	Annual Contests				Total	Total	Catch	Initial	%
	Cnt's <u>sch'd</u>	Rpts <u>rec'd</u>	Days <u>fished</u>	Angler <u>days</u>					
1990	485	378	380	6,289	59,981	12,092	0.202	245	2.0
1991	570	440	432	7,820	69,995	12,344	0.176	186	1.5
1992	704	586	604	10,842	99,608	20,777	0.209	400	1.9
1993	704	638	693	13,114	118,319	26,400	0.223	420	1.6
1994	814	676	743	13,963	130,809	35,330	0.270	599	1.7
Total	3,277	2,718	2,852	52,028	478,712	106,943	0.223	1,850	1.7

Mean values for anglers/day, hours/day, fish caught/day, and initial mortality/day (Table 2) were calculated using data in Table 1. We were also interested in determining the total anglers, effort, catch, and initial mortality for all tournaments conducted, not just for the tournaments for which we received reports. To estimate this, the data in Table 2 were expanded by using the total fishing days planned to derive estimated totals for each year (Table 3). To compare 1985–1989 and 1990–1994 results and pre- and post-Special Conditions periods, *t*-tests were used with significance set at the 5% level.



Table 2. Mean number of anglers/day, number of hours fished/day, number of fish caught/day, and initial mortality (fish/day) for black bass event and annual contests in California, 1990–1994.

Event Contests	Mean no.	Mean no.	Mean no.	Mortality/
<u>Year</u>	<u>anglers/day</u>	<u>hours/day</u>	<u>fish/day</u>	<u>day</u>
1990	86	814	177	1.2
1991	76	679	125	0.9
1992	89	825	162	1.1
1993	83	773	160	0.7
1994	90	836	205	0.7
Annual Contests				
1990	17	158	32	2.0
1991	18	162	29	1.5
1992	18	165	34	1.9
1993	19	171	38	1.6
1994	19	176	48	1.7

Table 3. Estimated total effort, catch, and initial mortality in black bass event and annual tournaments in California, 1990–1994.

<u>Year</u>	Event Contests			
	Estimated total no. <u>angler days</u>	Estimated total no. <u>angler hours</u>	Estimated total <u>catch</u>	Estimated initial <u>mortality</u>
1990	22,946	217,104	47,299	565
1991	22,324	198,574	36,645	328
1992	24,468	226,281	44,468	482
1993	26,297	246,522	51,072	341
1994	27,153	246,543	60,779	449
Total	123,189	1,135,024	240,263	2,165
<u>Year</u>	Annual Contests			
	Estimated total no. <u>angler days</u>	Estimated total no. <u>angler hours</u>	Estimated total <u>catch</u>	Estimated initial <u>mortality</u>
1990	7,675	73,164	14,757	296
1991	9,452	84,750	14,961	230
1992	12,597	115,851	24,200	464
1993	14,307	129,084	28,833	457
1994	16,220	151,893	41,018	703
Total	60,251	554,742	123,769	2,150



Simple linear regressions were conducted on the number of event contests per year, number of angler-days per year, number of black bass weighed in per year, the catch-per-hour per year, and the mean weight of black bass per year to determine if there were any significant trends between event contest data for the years 1985-1989 and 1990-1994. No comparison could be made of annual contests as no annual contest permits were issued for the years 1985-1994.

## RESULTS

### Event Contests

A total of 1,425 event permits was issued during 1990-1994 (Table 1) as compared to 824 permits for 1985-1989 (Lee et al. 1993), a 73% increase. Permits were issued for 48 different waters (Table 4). Sponsors returned 1,283 (90.0%) of the 1990-1994 reports as compared to 649 (78.8%) of the 1985-1989 reports (Lee et al. 1993). Return rates for 1990-1994 event contests ranged from a low of 87.2% in 1994 to a high of 93.5% in 1990. For 1985-1989, return rates ranged from 45.6% in 1985 to 93.6% in 1988 (Lee et al. 1993).

Table 4. Number and type of permits issued for California waters, 1990-1994. Waters are lakes or reservoirs unless otherwise indicated.

<u>Water</u>	<u>Event</u>	<u>Annual</u>	<u>Water</u>	<u>Annual</u>
Delta	291	338	Amador	38
Clear	141	238	Mendocino	30
Don Pedro	134	229	Trinity	27
Shasta	101	153	Los Banos	18
Castaic	101	143	Sutherland	16
Millerton	63	90	Havasu	15
Oroville	62	52	Pine Mountain	12
Folsom	57	47	Britton	11
Casitas	52	82	Hensley	10
Camanche	43	87	Pillsbury	9
Pine Flat	38	104	Black Butte	9
Berryessa	36	48	Miramar	9
San Vicente	27	84	Shastina	7
McClure	24	137	Big Sage	7
Cachuma	24	68	Copco	7
Pyramid	21	28	Big Bear	7
New Melones	19	84	Dorris	6
Lopez	19	56	Colorado River	5
El Capitan	18	79	Merle Collins	5
Hodges	17	55	Camp Far West	4
Isabella	13	11	Shaver	4
Tulloch	12	81	Salt Springs	4
Otay	11	45	Thermalito Afterbay	4



Table 4, cont'd.

<u>Water</u>	<u>Event</u>	<u>Annual</u>	<u>Water</u>	<u>Annual</u>
Perris	10	36	Woodward	4
Nacimiento	10	27	Morena	3
Success	8	111	Big Lake	3
San Antonio	8	5	Indian Valley	3
Puddingstone	7	4	Merced River	3
Piru	6	42	Walters Camp	2
Sonoma	6	31	Jennings	2
Almanor	6	26	Reservoir C	2
Iron Gate	6	7	Lower Colorado River	2
East Park	6	3	Irvine	2
Kaweah	5	57	Martinez	2
Santa Margarita	5	24	Jamestown	2
Silverwood	2	35	Butt	2
Pardee	2	28	Blue Lake	2
New Hogan	2	12	Davis	1
Skinner	2	8	Vail	1
Bullards Bar	2	5	Siskiyou	1
Bass Lake	1	35	San Carlos	1
Whiskeytown	1	16	Mojave	1
Antelope	1	13	Roberts	1
Ruth	1	11	Del Valle	1
Sacramento River	1	2	Cal-Pines	1
Natoma	1	1	Wohlford	1
San Luis	1	1	Mission Viejo	1
Elsinore	1	0		

The number of event contests conducted annually from 1990 to 1994 increased only slightly from 277 in 1990 to 303 in 1993 (Fig. 1). In comparison, the number of event contests during 1985–1989 rose from 57 in 1985 to 234 in 1989 (Fig. 1). The number of event contests was significantly greater in 1990–1994 ( $t = -3.676$ ;  $df = 8$ ;  $P < 0.01$ ) and was significantly and positively related to year over the entire period, 1989–1994 ( $r^2 = 0.812$ ,  $P < 0.01$ ) (Fig. 1). Team tournaments accounted for 66 to 83% of the 1990–1994 contests; the rest were draw tournaments. This is similar to the 1989–1993 results, 67 to 86% of which were team tournaments (Lee et al. 1993).

Significantly more (111,685) angler-days were expended from 1990 to 1994, compared to 1985 to 1989 (67,816) ( $t = -2.482$ ;  $df = 8$ ;  $P < 0.05$ ) (Fig. 2). The number of angler-days rose sharply from 1985 to 1988 and then increased only slightly to a peak in 1993. The number of angler-days/year had a significant and positive relation with year from 1985–1994 ( $r^2 = 0.721$ ,  $P < 0.01$ ).

Sponsors reported significantly more black bass caught during 1990–1994 (218,002) (Table 1) than in 1985–1989 (122,931) (Lee et al. 1993) ( $t = -2.778$ ;



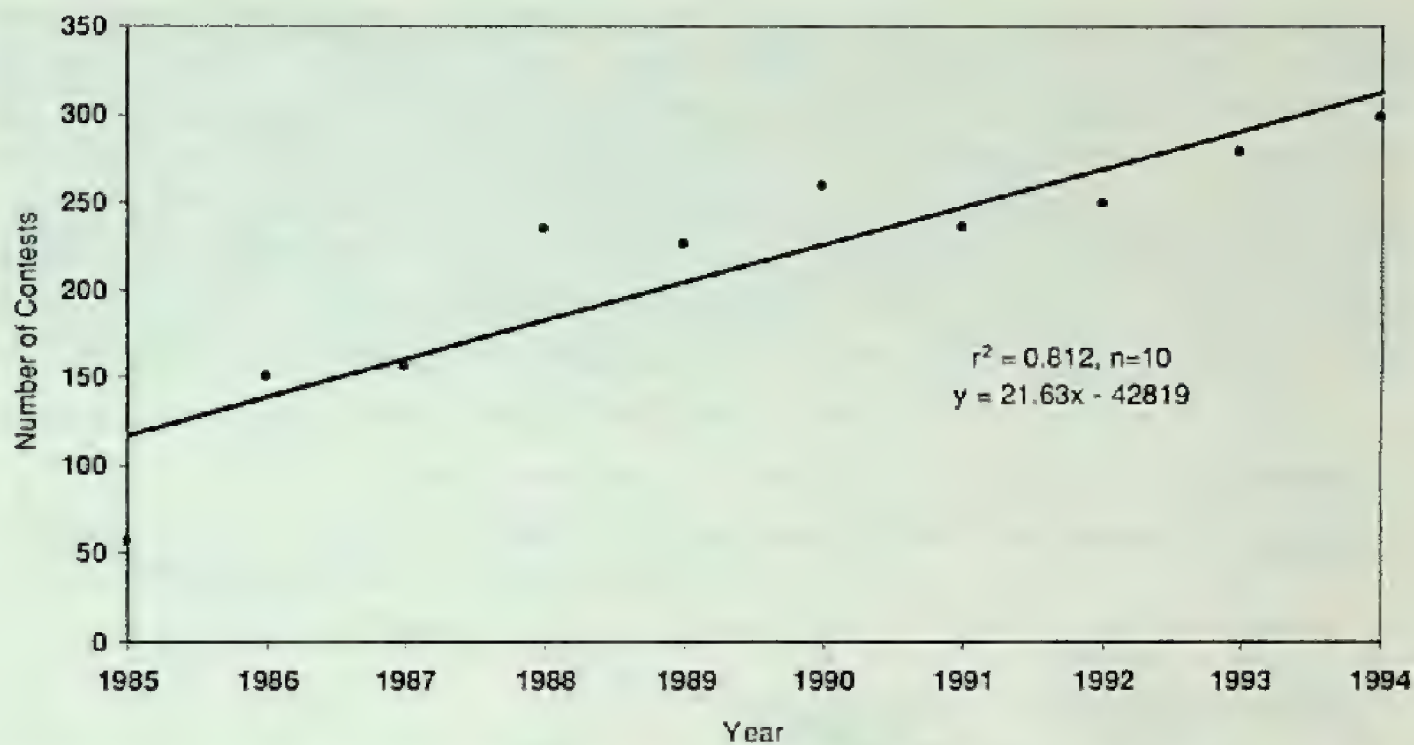


Figure 1. Trend in the number of event permits issued per year for black bass contests in California, 1985-1994.

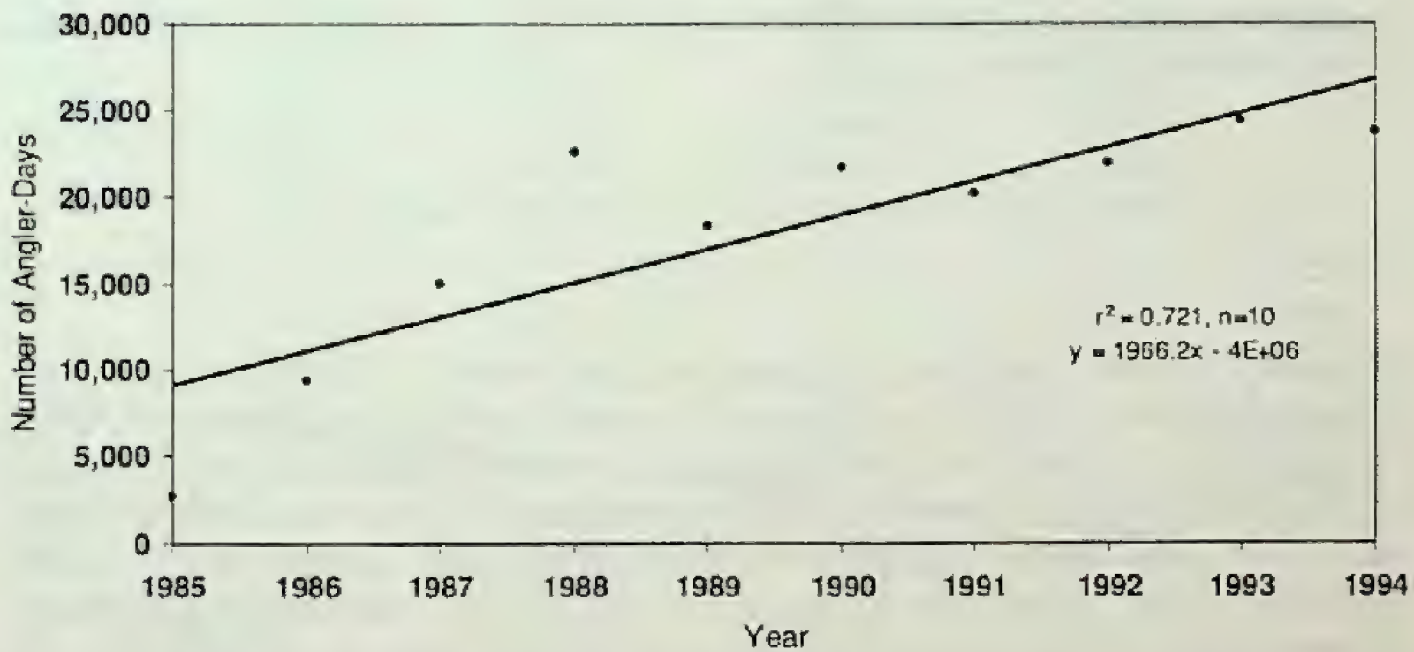


Figure 2. Trend in the umber of angler-days fished per year in California black bass event contests, 1985-1994.



df = 8;  $P < 0.05$ ) (Fig. 3). The number of fish weighed in increased significantly from 1985 to 1994 ( $r^2 = 0.772$ ,  $P < 0.01$ ). Annual catch per hour (CPH) for 1990–1994 event contests ranged from 0.184 in 1991 to 0.246 in 1994; the 5-year mean was 0.211. In 1985–1989, the CPH ranged from 0.172 in 1986 to 0.228 in 1987 and the 5-year mean was 0.192 (Fig. 4). The difference in the means of CPH was not significant ( $t = 0.328$ , df = 8,  $P > 0.05$ ). The linear regression (Fig. 4) indicated a small but not significant positive trend in CPH ( $r^2 = 0.144$ ,  $P > 0.01$ ). Estimates of total effort and catch for event contests were compared for 1990–1994 and 1985–1989. Total angler-days increased 44% (85,813

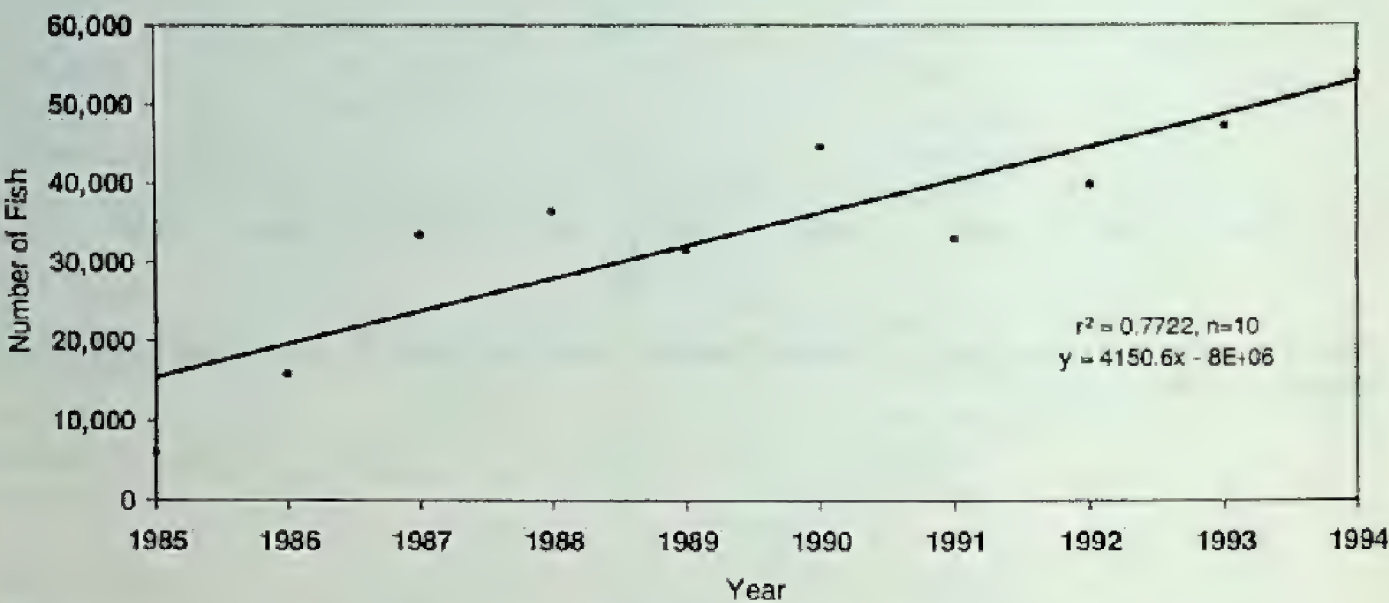


Figure 3. Trend in the umber of black bass weighed in per year during California black bass event contests, 1985-1994.

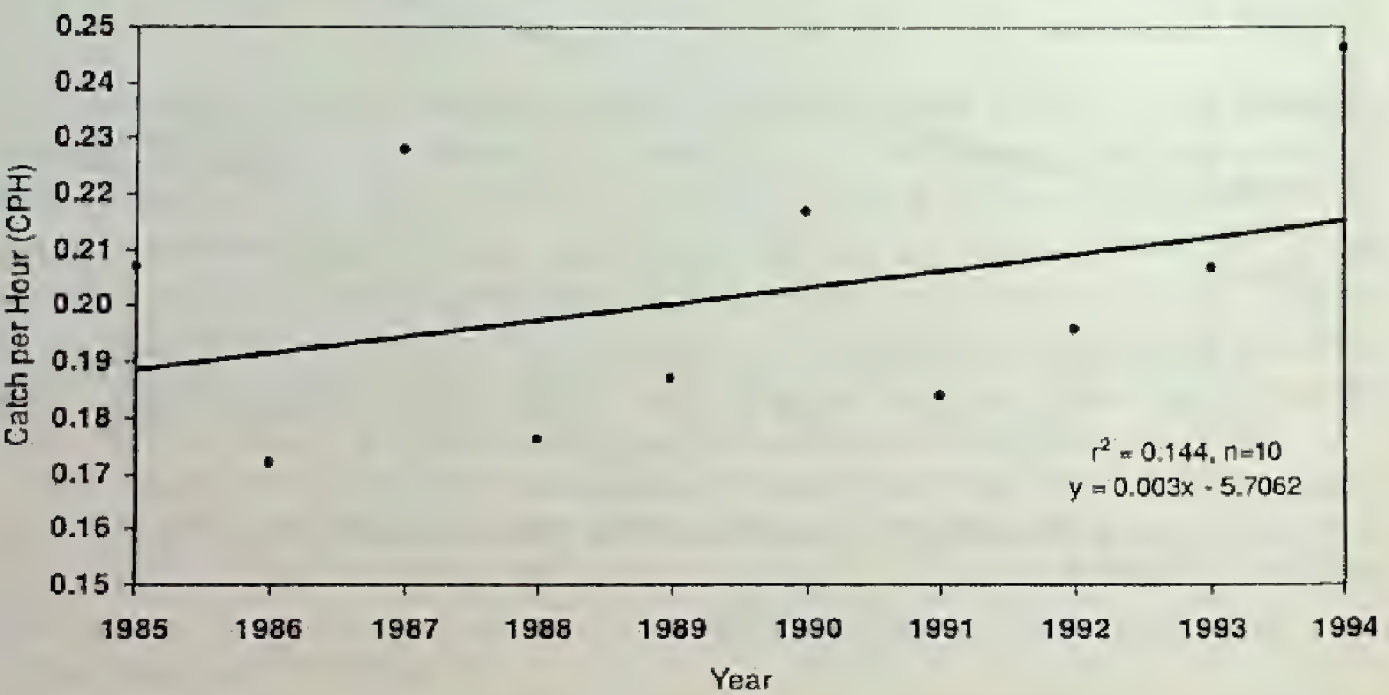


Figure 4. Trend in the annual catch per hour for California black bass event contests, 1985-1994.



to 123,189), total angler-hours increased 39% (816,558 to 1,135,024), the mean length of the angler-day decreased 3% (9.5 hours to 9.2 hours), and total catch of black bass weighed in increased 51% (158,954 to 240,263) (Table 3).

The 5-year mean weight of bass in event contests for 1990–1994 was 0.85 kg. (Table 5). The lowest annual mean weight, 0.80 kg, was recorded in 1991 and the highest, 0.95 kg, in 1993. In comparison, the 5-year mean weight of bass from 1985–1989 was 0.74 kg and ranged from 0.63 kg in 1985 to 0.79 kg in 1989. The difference in the means was significant ( $t = -2.784$ ;  $df = 8$ ;  $P < 0.05$ ) and the trend over the 10-year period showed a significant increase with year ( $r^2 = 0.830$ ,  $df = 8$ ,  $P < 0.01$ ) (Fig. 5).

Table 5. Total fish caught, total weight and mean weight of black bass weighed in at event and annual black bass tournaments in California, 1990–1994.

Event Contests	Total	Total	Mean
<u>Year</u>	<u>Fish</u>	<u>Weight(kg)</u>	<u>Weight(kg)</u>
1990	44,409	35,886	0.81
1991	32,937	26,212	0.80
1992	39,632	33,828	0.85
1993	47,212	39,914	0.95
1994	53,812	46,241	0.86
Total	218,002	182,081	0.85
Annual Contests			
1990	12,092	9,169	0.76
1991	12,344	9,147	0.74
1992	20,777	14,867	0.72
1993	26,400	19,304	0.73
1994	35,330	27,004	0.76
Total	106,943	79,490	0.74
Grand Total	324,945	261,571	0.81

Sponsors reported 1,960 dead bass at weigh-in in event contests from 1990 to 1994 (Table 1). Initial mortality rates showed large seasonal variations (Fig. 6) and were highest in June and lowest in February, March, and November. The 1990–1994 reported initial mortality rate was 0.9% as compared to the 1985–1989 rate of 1.85% (Lee et al. 1993). The pre-Special Conditions (1985–1988) initial mortality rate (1.92%) was significantly higher than the Special Conditions (1989–1994) rate (1.0%) ( $t = 4.092$ ;  $df = 8$ ;  $P < 0.05$ ). In all months except April, October, and December, initial monthly mortality rates were significantly lower in the Special Conditions period (Fig. 7).

Estimated total initial mortality for all event contests 1990–1994 was 2,165 fish (Table 3). Total mortality (defined as initial mortality plus mortality of fish after release) in black bass catch-and-release tournaments has been reported to be 1.3 to 1.9 times greater than initial mortality (May 1973, Welborn and Barkley 1974, Archer and Loyacano 1975, Seidensticker 1975, and Schramm et al. 1985). Using a factor of 1.9, the estimated total mortality was 5,664 fish during 1985–1989 (Lee et al. 1993).



Using this factor, we estimated total mortality for event contests from 1990 to 1994 to be 4,114 fish (estimated initial mortality 2,165 X 1.9) (Table 3). The pre-Special Conditions total mortality was significantly higher than the Special Conditions total mortality ( $t = 1.709$ ,  $df = 8$ ,  $P < 0.05$ ).

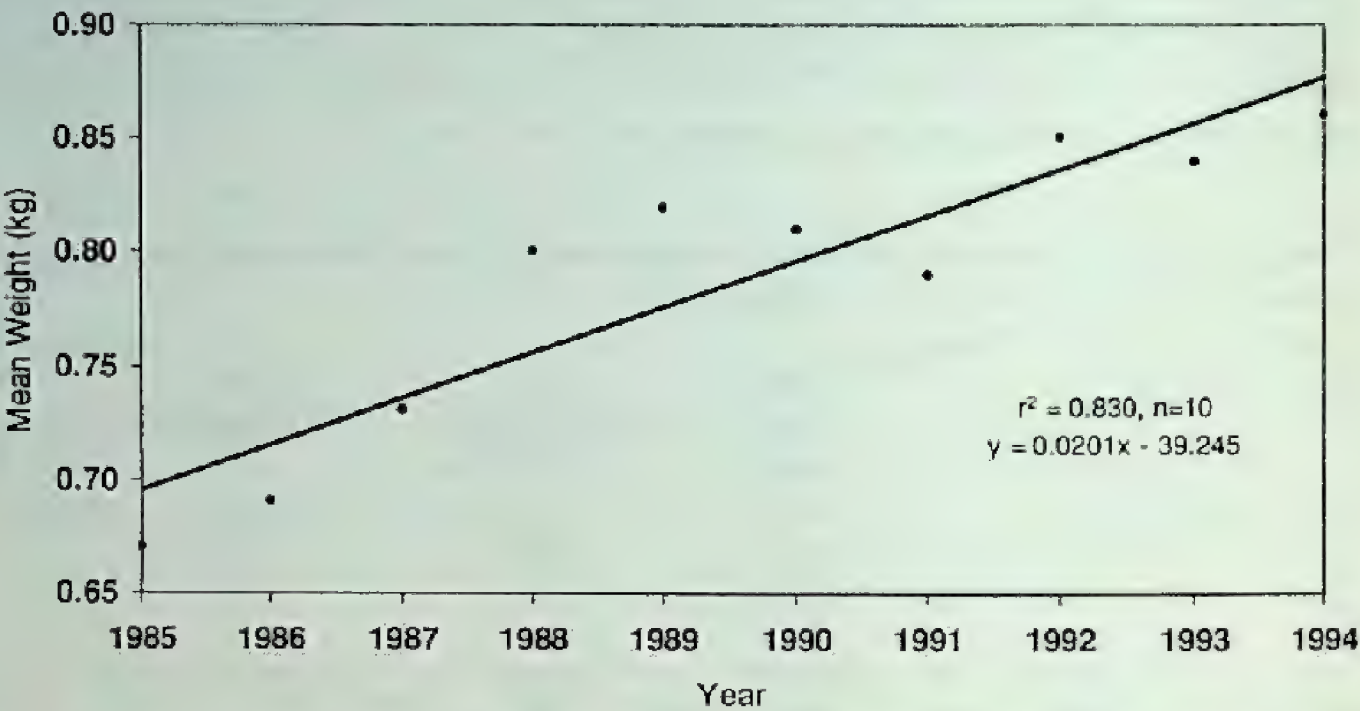


Figure 5. Trend in the annual mean weight of black bass weighed in during California black bass event contests, 1985-1994.

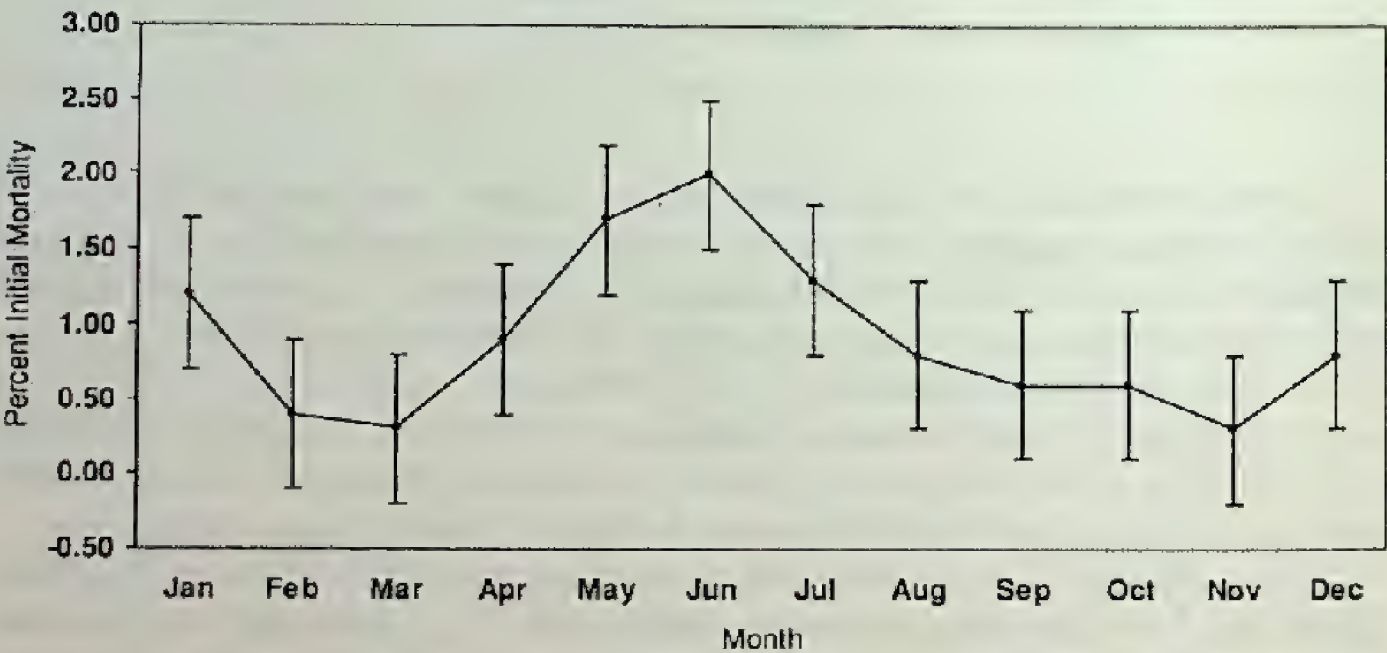


Figure 6. Monthly mean initial mortality in California black bass event contests, 1990-1994. Bars represent plus or minus 1 SD.



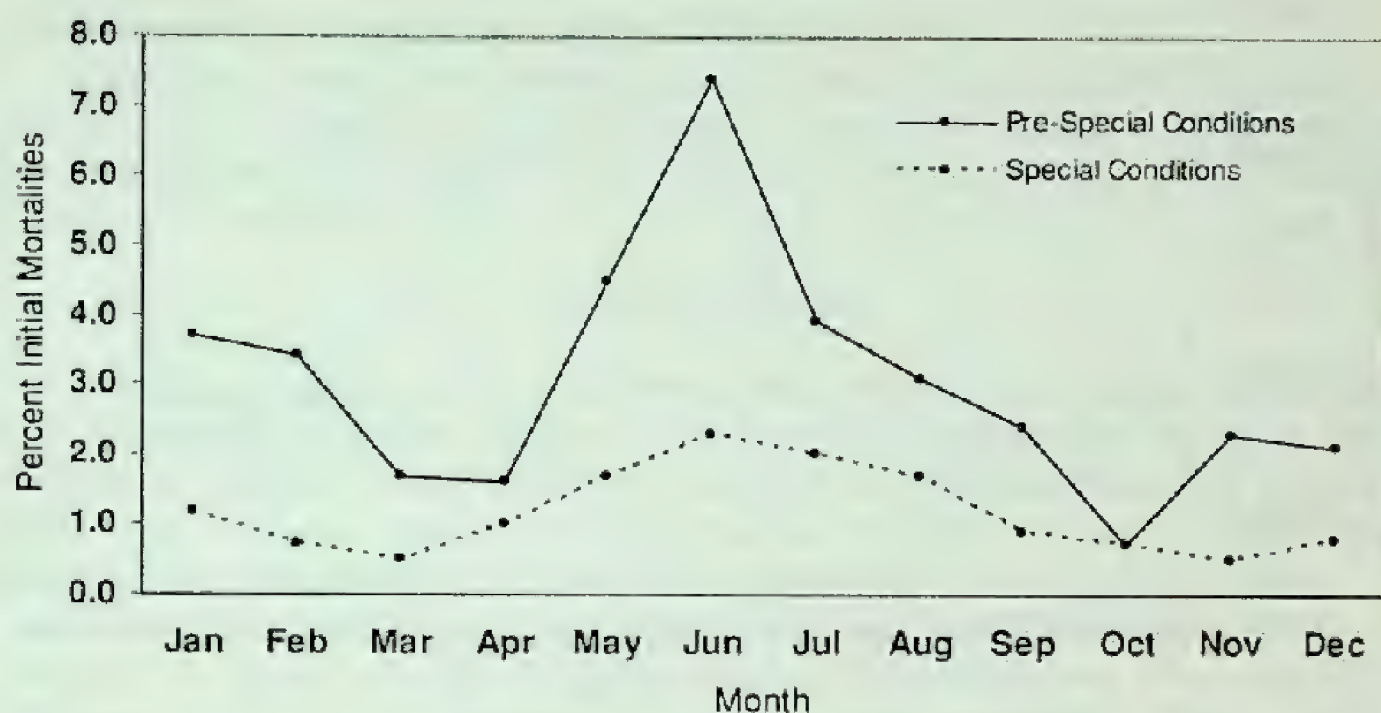


Figure 7. Mean monthly initial mortality for California black bass event contests, before, 1985-1988, and after, 1989-1994, implementation of "Special Conditions."

### Annual Contests

The CDFG issued 396 permits for 3,277 annual contests during 1990-1994 (Table 1). This was 72.7% fewer permits, but 2.3 times more contests, than were authorized by event permits during these years. Annual fishing contests were held on 94 different waters (Table 4). Sponsors returned 2,718 (82.9%) reports. Annual return rates ranged from 77.2% in 1991 to 90.6% in 1993. The number of annual permits issued each year increased steadily from 66 in 1990 to 95 in 1994. Draw tournaments accounted for 64 to 72% of the contests. The rest were team-type tournaments.

During annual fishing contests 1990 to 1994, 52,028 angler-days and 478,712 angler-hours of effort were expended. Sponsors reported 106,943 black bass weighed in (Table 1). Annual mean length of the angler-day, based on reported duration of individual contests, ranged from 9.0 to 9.5 hours, mean 9.2 hours. Mean annual CPH for all annual permit contests ranged from 0.176 in 1991 to 0.270 in 1994 with an overall mean CPH of 0.223 for the 5-year period. The 5-year mean weight of black bass weighed in was 0.74 kg, ranging from 0.72 kg in 1992, to 0.76 kg in 1994 (Table 5). The total estimated angler-days was 60,251, estimated angler-hours 554,742, and estimated number of black bass weighed in 123,769 (Table 3).

Sponsors reported 1,850 dead bass at weigh-in (Table 1). Based on reported initial mortality and the estimated total black bass caught during tournaments, we estimated the total initial mortality from 1990 to 1994 was 2,150 fish for annual contests (Table 3). Initial mortality rates for annual tournaments followed a pattern similar to that of event tournaments. They were lowest in February, March, and December and highest from June to August (Fig. 8). The small peak in mortality in annual permit contests in



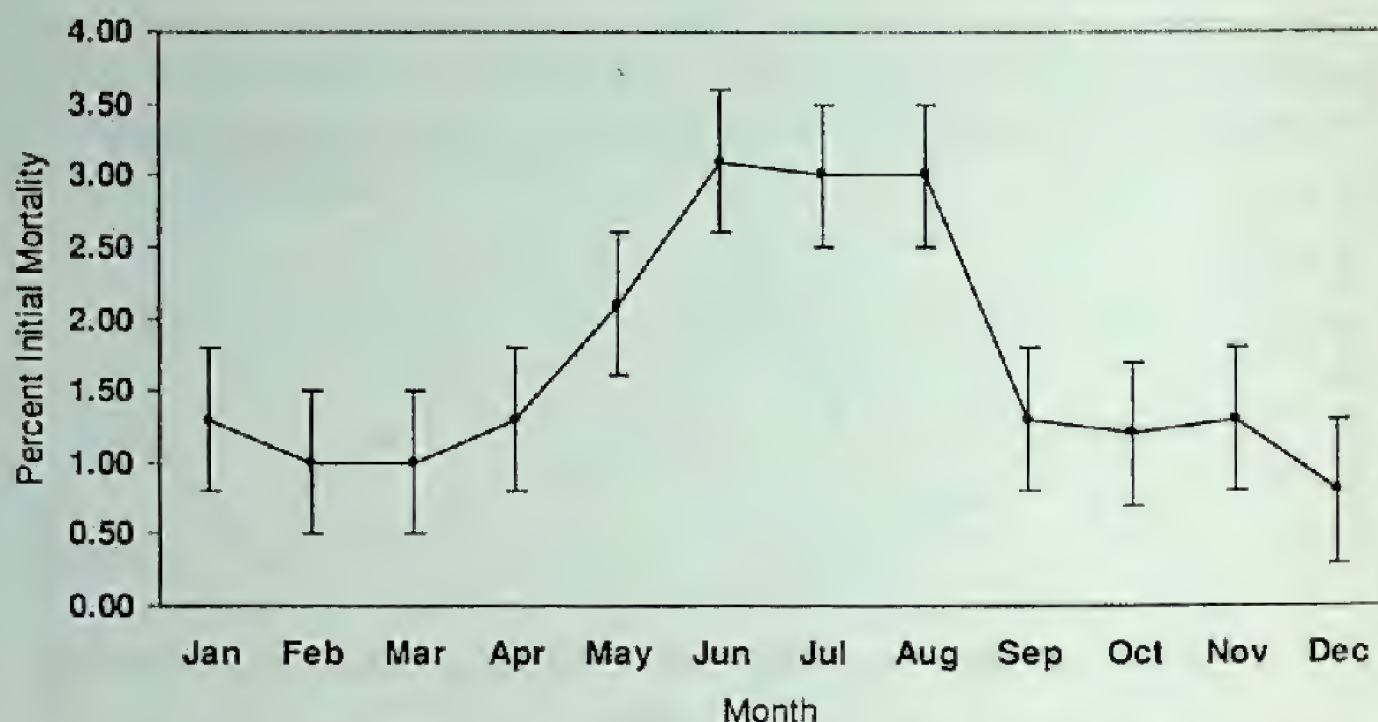


Figure 8. Estimated monthly initial mortality in annual California black bass contests, 1990-1994. Bars represent plus or minus 1 SD.

November may be biased due to high (3.3% and 3.1%) rates in 1991 and 1994. The initial mortality rates in November 1990, 1992, and 1993 were much lower: 0.0%, 0.4%, and 0.1%, respectively. Estimated total mortality of black bass in annual tournaments from 1990 to 1994 was 4,085 (estimated initial mortality of 2,150 x 1.9) fish (Table 3), slightly less than for all event permit tournaments (4,114). Estimated total mortality for all event and annual permit contests during 1990-1994 was 8,199 fish.

## DISCUSSION

### Event Contests

A comparison of 1985 to 1989 and 1990 to 1994 event-tournament data indicated that total effort (angler-days and angler-hours) increased with no significant increase in the CPH during the 2 periods (mean of 0.194 vs 0.210). This would suggest that, with a catch and release fishery, either the contestants are catching and releasing the same bass or the size of the black bass population has increased. The significant increase in the average weight of bass during the 1990 to 1994 compared to 1985 to 1989 (0.83 kg vs. 0.74 kg), in conjunction with the constant CPH, indicates that the bass population is not increasing, and most likely anglers continue to catch many of the same fish.

Initial mortality rates were generally highest in June of each year and were probably the result of additional stress placed on post-spawning bass by high water temperatures. Mortality rates were also elevated in mid-winter and most likely resulted from physiological stress placed on bass being caught from deep water. Typically, bass caught in the winter months are taken in water depths ranging from 3 to 15 m. Bass caught at these depths experience rapid depressurization and inflated swim



bladders which can lead to injury and predation (Lee 1992).

We believe the significant reduction in initial mortality between 1985 to 1993 and 1989 to 1994 (1.0 versus 1.92%) was directly attributable to the Special Conditions first implemented in 1989. We recommend that the Special Conditions for black bass contests be continued.

### Annual Contests

In addition to the 48 waters where event contests were held, annual-contest data were gathered on 47 waters where no event contests were held. The annual contests are held by numerous small bass clubs located throughout California that typically have 10 to 12 annual contests per year, whereas a limited number of commercial organizations sponsor between 3 and 50 event contests per year.

The significant difference in the weight of the bass during event contests as compared to annual contests, 0.85 kg versus 0.74 kg, may have been caused by differences in the skill levels of anglers in the 2 types of contests. Event contests typically have more "professional" anglers, who are likely to be more proficient in catching larger bass than anglers fishing in annual contests. Additionally, during event contests the prizes are more valuable and contestants may be more likely to cull fish in an attempt to amass a greater total weight per limit.

Initial mortality was almost twice as high for annual contests, 1.7%, as it was in event contests, 0.9% (Table 1). Possible explanations for this difference are: 1) bass clubs might not observe the Special Conditions regulations as closely as organizers who sponsor event-type contests, or 2) event sponsors might not report mortalities as accurately as annual sponsors. Typically, event sponsors will consider a fish alive if it moves, even though the fish has been stressed to the point that it will die when released (personal experience, ILP). Although the mortality rate was twice as great for annual contests as event contests, we believe mortalities are still at an acceptable level and have not had a detrimental impact on the black bass population. We believe this because there has not been a decrease in the overall CPH for black bass.

Annual contest reports provide baseline data for additional waters not fished by larger tournament sponsors. Hence, we recommend the continuance of the annual permitting system by the CDFG for fishing contests.

### ACKNOWLEDGMENTS

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## NOCTURNAL AND DIURNAL HAUL-OUT PATTERNS OF HARBOR SEALS (*PHOCA VITULINA RICHARDSI*) AT CASTRO ROCKS, SAN FRANCISCO BAY, CALIFORNIA

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Surveys of harbor seals, *Phoca vitulina richardsi*, at Castro Rocks, San Francisco Bay (SFB), California, were conducted from May 1998 through April 2001. Surveys were conducted at all hours of the day and disturbance data and seal responses were recorded continuously during these surveys. Harbor seals hauled out at Castro Rocks during the daytime and nighttime throughout the year. Over the course of the study period, mean nighttime counts were significantly higher than mean daytime counts. Maximum daytime and nighttime seal counts were recorded during the fall season. Tidal dependence alone was not a clear predictor of fluctuations in seal numbers hauling out during the daytime compared to the nighttime. Seals at this site experienced high levels of disturbance from a variety of sources during the daytime and significantly lower levels of disturbance at night. We believe that, in this highly urbanized environment, high levels of daytime disturbance contribute to the higher use of this haul-out site at nighttime, versus daytime. Given projected increases in the number of people living and working around SFB, protecting the integrity of haul-out sites in SFB is an important facet of protecting the harbor seal population.

### INTRODUCTION

In California, harbor seals (*Phoca vitulina richardsi*) come ashore onto rocky shores, mud flats, islands, or beaches. Haul-out locations are characterized by ease of



access to the water, proximity of food resources, and minimal disturbance levels (Scheffer and Slipp 1944, Loughlin 1974<sup>1</sup>). These sites serve as breeding and resting areas and hauling out may aid in thermoregulation (Feltz and Fay 1966). By hauling out in groups, seals are able to maximize the likelihood of detecting disturbances (da Silva and Terhune 1988). Haul-out sites provide researchers a means to assess the status of a given population; the maximum number of harbor seals present on a haul-out site provides a tool for estimating the local population size.

Numbers of seals on a given haul-out site vary with levels of disturbance, year, season, time of day, and tide height (Paulbitski 1975, Stewart 1981<sup>2</sup>, Slater and Markowitz 1983, Allen et al. 1984, Pauli and Terhune 1987, Grellier et al. 1996, Frost et al. 1999). Timing of the reproductive cycle and the thermoregulatory requirements associated with molting are two potential sources of seasonal variation, with many studies reporting high numbers of seals onshore during pupping and/or molting season (Kopec and Harvey 1995<sup>3</sup>, Frost et al. 1999).

Many researchers report that harbor seals haul out during the day, and forage during the night (Scheffer and Slipp 1944, Boulva and McLaren 1979, Thompson 1987<sup>4</sup>, Oxman 1995<sup>5</sup>). In addition, researchers have reported peak harbor seal counts at midday (Calambokidis et al. 1987, Watts 1996) or in the afternoon (Allen et al. 1984, Stewart 1984, Pauli and Terhune 1987). However, most of these studies did not incorporate nighttime data collection and, therefore, information on the nighttime haul-out patterns of harbor seals is limited. Among studies which collected nighttime data, Yochem et al. (1987) and Allen (1988)<sup>6</sup> documented that seals hauled out at all hours of the day and night at San Miguel Island and Point Reyes, California, respectively, but that numbers were highest around midday. Thompson et al. (1989) reported that their radiotagged seals in Orkney, Scotland, spent more time ashore during the day and suggested that this pattern may be due to seals returning to the water at night to feed.

Haul-out site use relative to tide varies by location; some sites are used exclusively

<sup>1</sup> Loughlin, T.R. 1974. The distribution and ecology of the harbor seal in Humboldt Bay, California. M.A. Thesis, Humbolt State University, CA, 70 pp.

<sup>2</sup> Stewart, B.S. 1981. Seasonal abundance, distribution, and ecology of the harbor seal, *Phoca vitulina richardsi*, on San Miguel Island, California. M.S. Thesis. San Diego State University, 66 pp.

<sup>3</sup> Kopec, D., J.T. Harvey. 1995. Toxic pollutants, health indices, and population dynamics of harbor seals in San Francisco Bay, 1989-91: A final report. Technical Publication. Moss Landing, CA: Moss Landing Marine Laboratory, P.O. Box 450, Moss Landing, CA, USA 95039-0450.

<sup>4</sup> Thompson, P.M. 1987. The effect of seasonal changes in behavior on the distribution and abundance of common seals, *Phoca vitulina*, in Orkney. Ph.D. Dissertation, University of Aberdeen, Scotland. 227 pp.

<sup>5</sup> Oxman, D.S. 1995. Seasonal abundance, movements and food habits of harbor seals (*Phoca vitulina richardsi*) in Elkhorn Slough, California. M.S. Thesis. Moss Landing Marine Laboratories, California State University, Stanislaus. 126pp.

<sup>6</sup> Allen Miller, S.G. 1988. Movement and activity patterns of harbor seals at the Point Reyes Peninsula, California. M.S. Thesis, University of California at Berkeley. 70 pp.



at low tides, others at medium or high tides, while some show haul-out patterns independent of the tide level (Pauli and Terhune 1987, Thompson and Miller 1990, Kopec and Harvey 1995<sup>7</sup>). Pauli and Terhune (1987) suggest that there is an interaction between temporal factors and tidal influences, with tide playing a stronger role in areas where haul-out sites are only available at low tides, and time of day playing a stronger role in areas where haul-out sites are available at all tides. They note that in general, more seals are recorded on the haul-out when the low tide occurs in the afternoon.

Human activities may alter behavioral patterns of harbor seals (Paulbitski 1975, Schneider and Payne 1983, Slater and Markowitz 1983, Terhune and Almon 1983, Pauli and Terhune 1987, Suryan and Harvey 1999). Primary sources of human disturbance to harbor seals include boats, kayaks, jet skis, aircraft, foot traffic, and dogs in the vicinity of the haul-out site. Seals are sensitive to both visual and acoustic disturbances.

If the frequency and magnitude of disturbances are sufficient, seals may permanently abandon a site (Kenyon 1972, Newby 1973). For example, Paulbitski (1975) and Allen (1991)<sup>8</sup> suggested that human disturbance played a role in harbor seals' abandonment of the Strawberry Spit haul-out site in San Francisco Bay, California. Increased development pressures and human foot traffic beginning in the late 1970's caused a precipitous drop in the number of seals that used this haul-out site. Strawberry Spit was abandoned by the seals in the mid-1980's, and no re-establishment of this site has occurred to date. Paulbitski (1975) reported night use of Strawberry Spit prior to that haul-out site's abandonment, and Paulbitski (1975) and Allen et al. (1984) suggested that human disturbance may cause seals to haul out during the night to avoid high levels of daytime disturbance.

From 1998 to 2001, we collected daytime and nighttime data on the haul out and behavioral patterns of seals at Castro Rocks, a primary haul-out site in San Francisco Bay, California. Our extensive database for this site allowed us to address seasonal, temporal, tidal, and disturbance factors in comparing daytime and nighttime haul-out patterns. Furthermore, we address the relationship of human activities to haul-out site use at Castro Rocks.

## STUDY AREA AND METHODS

The Castro Rocks haul-out site is a chain of six rock formations located in northern San Francisco Bay (SFB), near the Richmond-San Rafael Bridge (37.93° N, 122.41° W) (Fig. 1). The rocks stretch approximately 250 m in a southwesterly direction from the bridge, beginning approximately 17 m from the bridge and ending approximately 75 m from the bridge. Castro Rocks is submerged at tides above approximately 1.5 m, and is therefore used by seals only at low to medium tides. Castro Rocks is the second largest pupping site in the SFB and previous researchers have reported maximum seal

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<sup>7</sup> Op.Cit.

<sup>8</sup> Allen, S.G. 1991. Harbor seal habitat restoration at Strawberry Spit, San Francisco Bay. Report to the U.S. Marine Mammal Commission. 44 pp. CPI Electronic Publishing, 8399 East Indian School Road, Scottsdale, AZ USA 85251-2853.



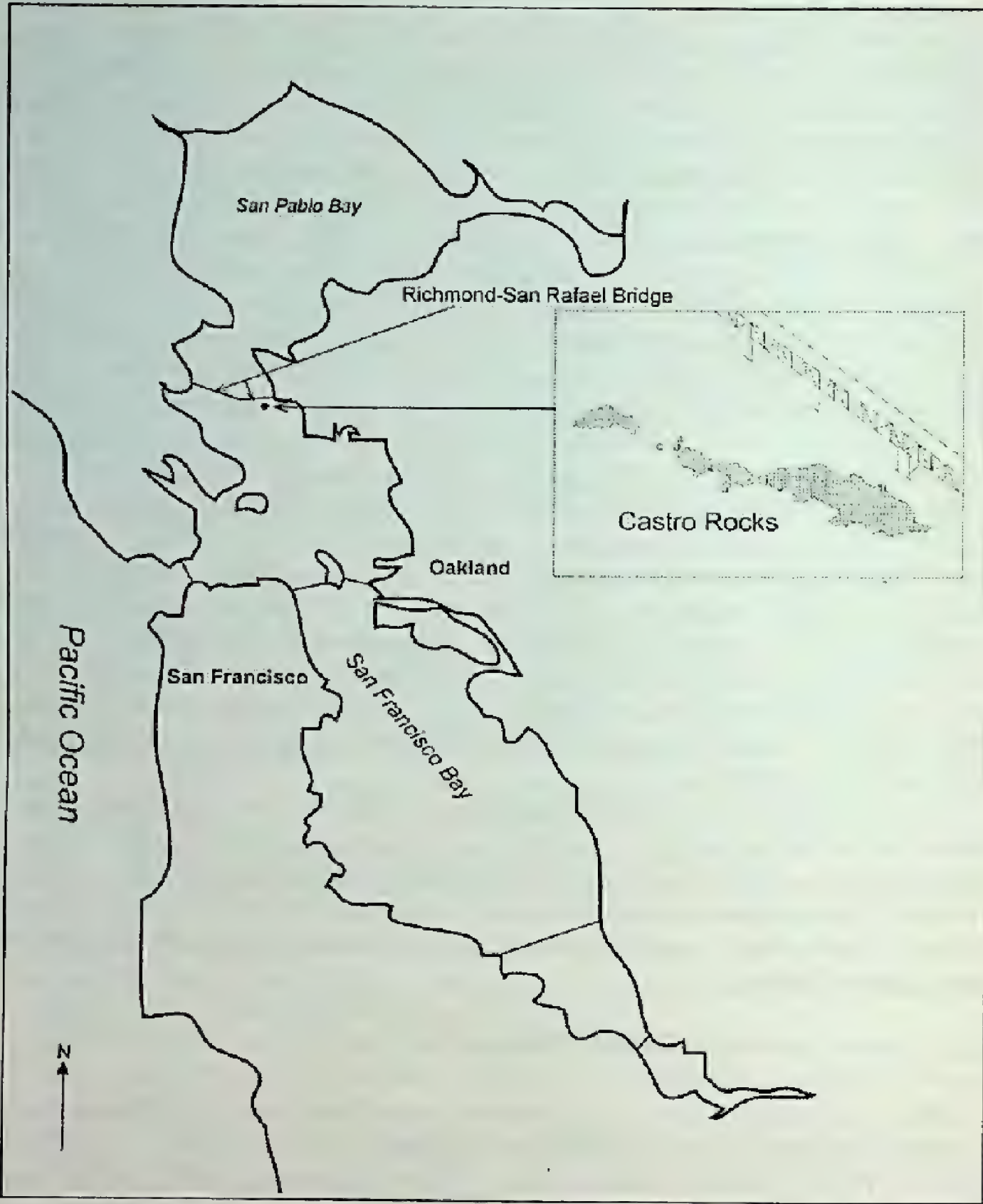


Figure 1. Location of the Castro Rocks harbor seal haul-out site in San Francisco Bay, California.



numbers during pupping season at this site (mid-March – May) (Kopeck and Harvey 1995<sup>9</sup>).

San Francisco Bay is a highly urbanized environment. In excess of 61,000 automobiles cross the Richmond-San Rafael Bridge each day (C. Morton, California Department of Transportation, personal communication). In addition, the waters near the haul-out site support a high volume of watercraft, including tankers, ferries and recreational boats.

We collected data at Castro Rocks from May 1998 through April 2001. Surveys were conducted 3-7 days/week and 2 nights/week, and were centered around the low tide when possible. For the purposes of this study, we defined daytime surveys as those taken during daylight hours and nighttime surveys as those taken in the absence of daylight, with the aid of bridge lighting. During surveys, we counted the total number of seals present on the haul out site once every 30 minutes. Seals were observed from an observation platform located on the Richmond-San Rafael Bridge, approximately 30 m above the eastern end of the haul-out site.

Before comparing numbers of seals on the haul-out by year, season, and during the daytime versus during the nighttime, we removed the influence of tide height by running a series of correlations on seal counts and tide height. We successively removed data from surveys taken from higher tide heights, until there was no longer a correlation between tide height and number of seals on the haul-out site. At tide heights of  $\leq 0.27$  m, there was no correlation between seal count and tide height. In order to avoid autocorrelation of seal counts taken within the same tidal cycle, we calculated a mean count for each survey (hereafter referred to as mean survey counts). To determine whether seal counts at Castro Rocks differed by year, we ran a Mann-Whitney U Test on mean survey counts (for tide heights of  $\leq 0.27$  m) for the two study years for which we had a full year of data, 1999 and 2000. To evaluate whether seasonal counts differed by year, we ran one-way ANOVA's on mean survey counts (for tide heights of  $\leq 0.27$  m) by season between years. We defined harbor seal 'seasons' in SFB as follows: pupping (March 15 – May 31), molting (June 1 – August 15), fall (August 16 – November 15) and winter (November 16 – March 14). Tide heights were determined using tides listed in Tides & Currents Pro 2.5 for the Chevron Long Pier, located approximately 825 m from Castro Rocks.

Using a 2-sample t-test that did not assume equal variances between samples (Zar 1996), we compared daytime and nighttime mean survey counts using data taken over the entire study period when the tide height was  $\leq 0.27$  m. For within-season comparisons of daytime versus nighttime mean survey counts, we first ran correlations for each season between seal count and tide height until the correlation was lost within each season (as was done when examining the overall study period). We then compared daytime and nighttime mean survey counts within each season, again using 2-sample t-tests. In order to further analyze seasonal differences in daytime and nighttime haul-out site use, we compared the daytime and nighttime mean tide heights at which count data were collected (hereafter referred to as mean survey tide height).

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<sup>9</sup> Op. Cit.



We recorded all potential sources of disturbance to the seals, both human and non-human in origin, regardless of whether or not seals responded. Seal responses to disturbance were recorded continuously during all research surveys. Responses included head alerts, seals moving towards the water en masse, and seals flushing into the water (Allen 1991)<sup>10</sup>. A flush response was recorded if at least one seal entered the water in association with a disturbance.

Patterns in disturbances were examined and predominant disturbance sources were identified. The frequency of seal responses to disturbance per hour of field time at Castro Rocks during the daytime and nighttime was analyzed using Mann-Whitney U tests (Zar 1996). In addition, we examined seasonal differences in the frequency of seal responses per hour of field time during the daytime and nighttime. Days and nights when no seals were present (day  $n = 4$ , night  $n = 0$ ) were excluded from the disturbance analyses. The alpha level of confidence for statistical significance was 0.05 for all measures.

## RESULTS

Regular use of Castro Rocks by harbor seals was recorded throughout the study period. There was no significant difference in seal numbers at Castro Rocks in 1999 versus 2000. In addition, there was no significant difference in seal numbers by season across years, with the exception of the fall season ( $F = 5.78$ ,  $df = 128$ ,  $p < 0.005$ ). Mean survey counts in the fall season increased from 1998 (seasonal mean = 94.82) to 1999 (seasonal mean = 106.52) to 2000 (seasonal mean = 122.25).

Overall (May 1998 – April 2001), nighttime mean survey counts (mean = 100.6,  $n = 156$ , range 2.0-200.0) of harbor seals at Castro Rocks were significantly higher than daytime mean survey counts (mean = 87.1,  $n = 412$ , range 0-192.0) ( $t = -3.46$ ,  $df = 229$ ,  $p < 0.001$ ). For the overall study period, peak seal counts were recorded during the nighttime between the hours of 2200 and 0400 (Fig. 2). The maximum seal count during both the daytime (201) and nighttime (212) was recorded during the fall season. Daytime mean survey counts ( $n = 121$ ) were significantly higher than nighttime mean counts ( $n = 11$ ) during the pupping season ( $t = 4.52$ ,  $df = 12$ ,  $p < 0.001$ ), while nighttime mean survey counts ( $n = 77$ ) during the fall season were significantly higher than daytime mean survey counts ( $n = 66$ ) ( $t = -4.39$ ,  $df = 140$ ,  $p < 0.0001$ ) (Fig. 3). There was no significant difference between mean daytime and nighttime survey counts during both the molting and winter seasons. When comparing mean survey counts within each season across years, results for the molting, fall and winter seasons were consistent with the overall dataset: no significant differences in daytime versus nighttime mean survey counts for the molting and winter seasons, while nighttime mean survey counts in the fall season were significantly higher than daytime mean survey counts across all years (1998:  $t = -2.10$ ,  $df = 42$ ,  $p < 0.05$ ; 1999:  $t = -3.91$ ,  $df = 35$ ,  $p < 0.001$ ; 2000:  $t = -2.24$ ,  $df = 45$ ,  $p < 0.05$ ). Mean survey counts during pupping season were significantly higher during the daytime in both 1999 ( $t = 2.62$ ,  $df = 6$ ,  $p < 0.05$ ) and 2001 ( $t = 7.41$ ,  $df = 20$ ,  $p$

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<sup>10</sup> Op. Cit.



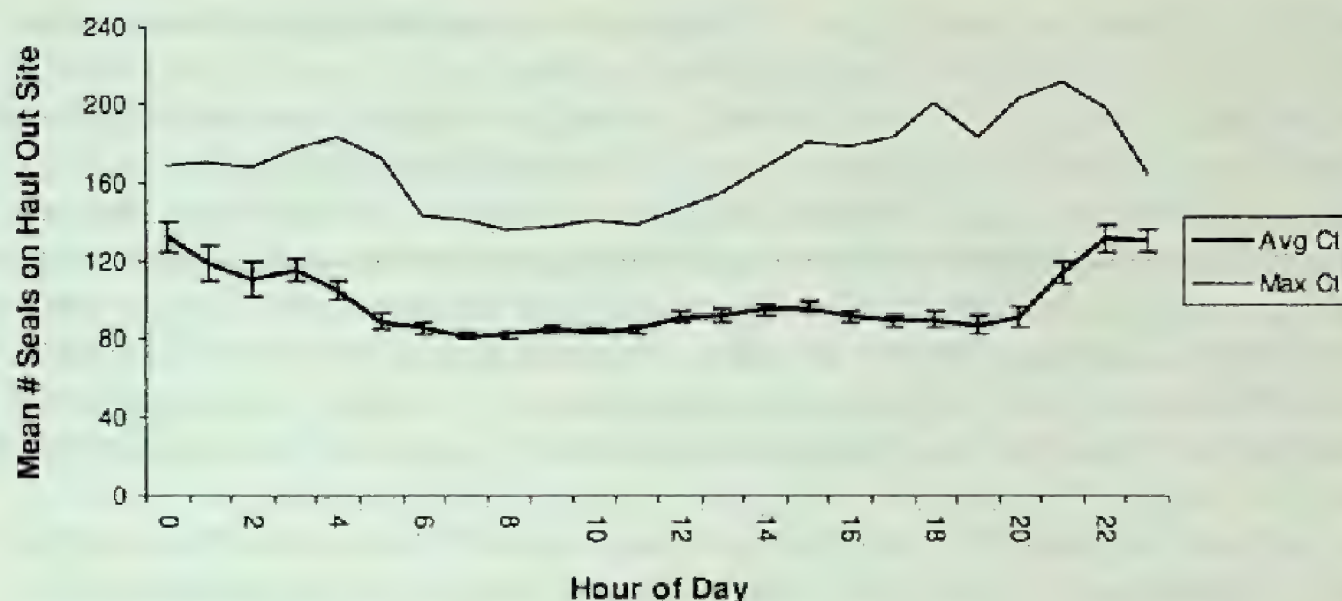


Figure 2. Average ( $\pm$  SE) and maximum number of harbor seals hauled out on Castro Rocks during the daytime and nighttime at each hour of the day. Only counts taken when the survey tide height was  $\leq 0.27$  m or less were used.

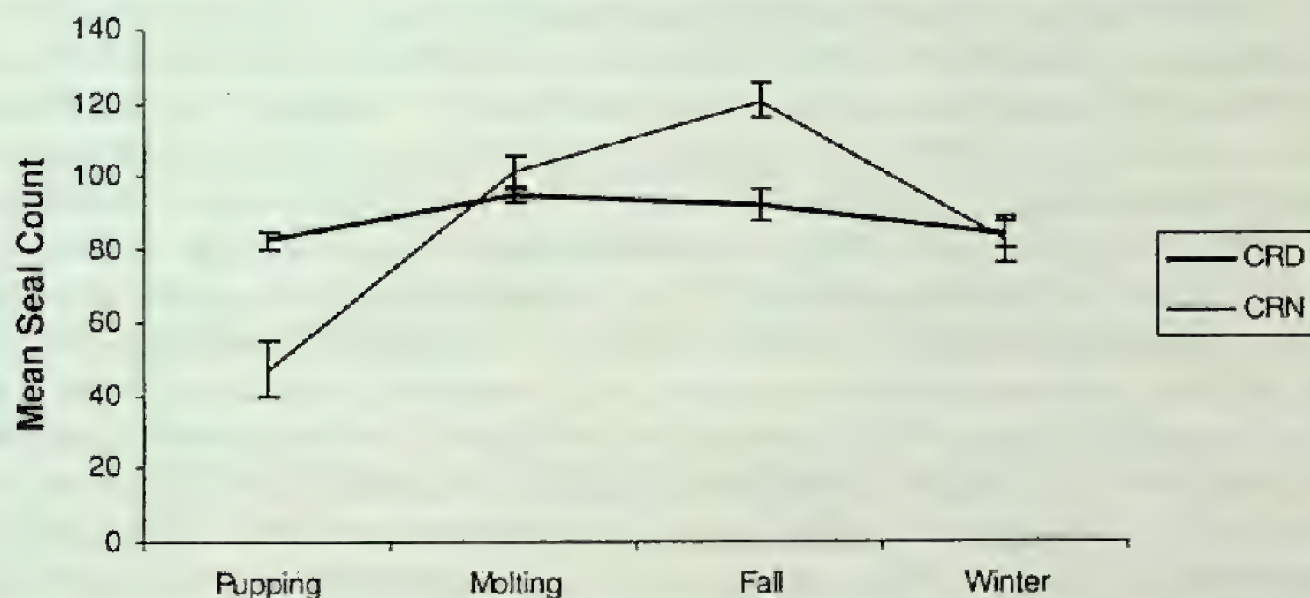


Figure 3. Daytime and nighttime mean number ( $\pm$  SE) of harbor seals hauled out on Castro Rocks during pupping, molting, fall and winter.

$< 0.0001$ ). However, due to a lack of data collected during the nighttime in the 1998 ( $n = 2$ ) and 2000 ( $n = 1$ ) pupping seasons, analyses could not be run on these years.

There was no significant difference in the daytime and nighttime mean survey tide height for the overall study period. However, when comparing daytime and nighttime mean survey tide heights within each season, the daytime mean survey tide height (mean = 0.107 m) was significantly higher than the nighttime mean survey tide height (mean = 0.061 m) during the fall season ( $t = 2.12$ ,  $df = 125$ ,  $p < 0.05$ ), as well as during the winter season (daytime mean = 0.114 m, nighttime mean = 0.021 m) ( $t = 2.87$ ,  $df = 67$ ,



$p < 0.01$ ). There was no significant difference in the daytime and nighttime mean survey tide height during the pupping and molting seasons.

Harbor seals at Castro Rocks were exposed to a higher number of potential disturbances during the daytime ( $n = 1464$ , 1.53 potential disturbances/hr) than during the nighttime ( $n = 121$ , 0.57 potential disturbances/hr). Of all disturbances that were correlated with a response from the seals during the daytime ( $n = 1235$ ), the major sources were automobiles (0.563 responses/hr) and watercraft (0.194 responses/hr) (motorboats, sailboats, tankers, personal watercraft such as kayaks and jet skis). Of all seal responses recorded during the nighttime ( $n = 69$ ), major associated sources included automobiles (0.137 responses/hr) and "other" (e.g., wildlife, people, and light sources from a nearby pier) (0.043 responses/hr).

Of disturbances causing seals to leave the haul-out site during the daytime ( $n = 365$ ), 0.090 flushes/hr were due to watercraft. Other daytime sources included "other" (e.g., floating debris, birds, and workmen on the bridge) (0.084 flushes/hr) and automobiles (0.019 flushes/hr). Of the 25 disturbances to cause animals to flush during the night, "other" was the primary cause (0.028 flushes/hr). Automobiles and aircraft caused one flush each, or 0.005 flushes/hr. Unknown sources caused 0.183 flushes/hr during the daytime and 0.080 flushes/hr during the nighttime.

The frequency of seal responses during the daytime ( $1.27 \pm 0.076$  responses/hr, or approximately one response every 0.78 hours) was significantly greater than during the nighttime ( $0.30 \pm 0.048$  responses/hr, or approximately one response every 3.33 hours) ( $U = 131692.5$ ,  $p < 0.0001$ ). This includes all disturbances seen to cause a reaction by the seals (head alert, approach water, or flush). We then examined only those disturbances that were correlated with seals flushing off the haul-out site. Disturbances associated with seals flushing were significantly more frequent during the daytime ( $0.42 \pm 0.032$  flushes/hr) than during the nighttime ( $0.11 \pm 0.032$  flushes/hr) ( $U = 125528.5$ ,  $p < 0.0001$ ).

Across all seasons, seal responses to disturbance per hour were significantly higher during the daytime than during the nighttime (pupping:  $U = 8496.5$ ,  $p < 0.001$ ; molting:  $U = 5357.5$ ,  $p < 0.001$ ; fall:  $U = 5555.0$ ,  $p < 0.001$ ; winter:  $U = 13558.0$ ,  $p < 0.001$ ). In addition, flushes per hour were significantly higher during the daytime than during the nighttime for all seasons except pupping (molting:  $U = 5107.5$ ,  $p < 0.05$ ; fall:  $U = 5099.5$ ,  $p < 0.001$ ; winter:  $U = 12945.0$ ,  $p < 0.001$ ); no flushes were recorded during the nighttime in the pupping season.

## DISCUSSION

Castro Rocks serves as an important harbor seal haul-out site within San Francisco Bay and was consistently used year-round by seals at all hours of the daytime and nighttime. The lower numbers of seals in the fall of 1998 may be influenced by 1998 El Niño Southern Oscillation event; harbor seal numbers at other sites in central California were lower during this year compared with previous years (Kopec and Harvey 1995<sup>11</sup>,

<sup>11</sup> Op. Cit.



Sydeman and Allen 1999). However, this effect was not observed in the other 1998 seasons used for comparisons (molting 1998 and winter 98/99). Data were not available for a pupping season comparison, as we did not begin collecting data until May 1998.

Although we recorded a slight peak in the number of seals hauled out in the mid-afternoon (1300-1500 hr), as other researchers have noted, our highest overall numbers were recorded during the nighttime. During our study period, seasonal maximum numbers of harbor seals at Castro Rocks ranged from 121 to 201 during the daytime, and from 56 to 212 during the nighttime. Despite the fact that most studies report maximum seal counts during the pupping or molting season, and that Castro Rocks is a major pupping site in the Bay, we recorded our highest counts during the fall season. Given that the total population of harbor seals in San Francisco Bay is estimated at approximately 500 animals (R. Reed, California Department of Fish and Game, personal communication), our maximum counts at Castro Rocks represent a substantial proportion of the Bay population.

Although fewer seals were seen at Castro Rocks during higher tides, tidal dependence alone was not a clear predictor of fluctuations in seal numbers hauling out during the daytime compared to the nighttime over the entire study period. While there was no significant difference in the daytime and nighttime mean survey tide heights for the overall study period, significantly more seals hauled out at Castro Rocks during the nighttime than during the daytime. In addition, seasonal differences in the number of seals hauled out during the daytime and nighttime cannot be explained solely by tide height. For example, although higher nighttime counts during the fall coincided with lower tide heights, there were higher daytime counts during pupping season despite no difference in daytime versus nighttime tide heights. Therefore, other factors must be contributing to harbor seal haul-out patterns at this site.

The significantly lower number of seals hauled out at Castro Rocks at night during the pupping season may be related to the presence of mother-pup pairs, although the reasons for this pattern were not clear in our analysis. Males may have moved into the area in order to gain access to females, as harbor seals mate around weaning. It is possible that, as Thompson et al. (1989) noted for male seals at their study site in Scotland, these males may be hauling preferentially during the day and moving off into the water to feed at night. Alternately, seals may be foraging more at night in preparation for the molting season, which immediately follows the pupping season and during which time seals increase their proportion of time hauled out (Boily 1995).

It is likely that, in the highly urbanized environment of San Francisco Bay, human disturbance plays a role in the nighttime use of Castro Rocks. Harbor seals at this site were exposed to a higher frequency of disturbance during the daytime than during the nighttime. Seal responses to two primary sources of disturbance, watercraft and automobiles, were recorded more frequently during the daytime than during the nighttime. In addition, seals were flushed off the haul-out site due to disturbance more frequently during the daytime than during the nighttime. The higher frequency of daytime flushes may have contributed to the lower daytime means during our study period. For example, if animals that were flushed off the haul-out site due to a daytime disturbance did not rehaul in time for the next survey (or for the remainder of that tidal



cycle), the subsequent count would have been lower, thereby contributing to a lower daytime mean count.

In addition, according to air acoustics studies at this site<sup>12</sup>, the average hourly  $L_{eq}$ <sup>13</sup> noise levels during the daytime (65 to 81 decibels; hourly maximum noise levels ranged from 76 to 118 decibels) were significantly higher than during the nighttime (60 to 78 decibels; hourly maximum noise levels ranged from 74 to 103 dBA) ( $t=8.49$ ,  $p<0.0001$ ,  $df=22$ ). Allen et al. (1984) and Paulbiski (1975) reported a shift from diurnal to nocturnal hauling out by harbor seals at another haul-out site in San Francisco Bay, and suggested that this shift was in response to high daytime disturbance levels. Nighttime haul out in response to daytime disturbance has also been reported for captive harbor seals (Brasseur et al. 1996). Low levels of disturbance are one factor determining where harbor seals choose to haul out (Scheffer and Slipp 1944, Loughlin 1974). If disturbance levels are lower at night, and given a sufficiently low tide, our data suggest that seals may use haul-out sites during the nighttime in higher numbers in areas with high levels of daytime disturbance.

Suryan and Harvey (1999) noted that disturbance to harbor seals may have considerable impact in areas where haul-out space is limited, and that this may be of particular concern when considering suitable haul-out for mother-pup pairs. Haul-out space in the San Francisco Bay is indeed limited by the large human population of the area, and making use of available haul-out sites at night may be a necessary response for SFB seals.

Another factor that may influence haul-out patterns at this site is seasonal variation in prey availability in SFB, such as the winter spawning season of Pacific herring, *Clupea pallasii*. However, year-round availability of prey near Castro Rocks allows seals to use this site during all seasons, in contrast to other haul-out sites in the SFB which are used only seasonally. To date, no studies of harbor seal prey species in the north SFB have been conducted and the role of prey availability in influencing daytime versus nighttime use of Castro Rocks is not known.

Weather variables were considered as a possible factor in seasonal differences in the timing of haul-out site use at Castro Rocks. For example, consistent use of this site at night during the fall season coincides with some of the warmest weather in the SFB area, and it has been suggested that harbor seals may leave a haul-out site during warm weather (Watts 1996). However, daytime air temperatures were significantly higher than nighttime air temperatures for all seasons, but nighttime seal counts were only significantly higher than daytime counts during the fall season. Further, despite higher air temperatures recorded during the daytime in pupping season, daytime seal counts

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<sup>12</sup> Air acoustics information is collected as part of an ongoing monitoring project associated with the seismic retrofit construction at the Richmond-San Rafael Bridge.

<sup>13</sup>  $L_{eq}$  levels are the average A-weighted noise level recorded during the measurement period (30 minute interval). A-weighted noise levels are the sound pressure level in decibels which de-emphasize the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.



were significantly higher during this season. Previous research at this site indicates that there is little correlation between weather variables and the number of seals on Castro Rocks (Grigg et al. 2001)<sup>14</sup>.

Other researchers have noted the lack of consistent relationships between numbers of seals on a haul-out site and weather variables (Loughlin 1978, Brown and Mate 1983). Given the Mediterranean climate of the SFB area, it is not surprising that weather variables are not a strong predictor of harbor seal haul-out site use in SFB.

Harbor seals in SFB are already subject to pressures from pollution, shoreline development, and increasing levels of human activity (Fancher 1987<sup>15</sup>, Risebrough et al. 1980<sup>16</sup>). Disturbances that cause seals to flush off a haul-out site may result in increased energy expenditures, due to decreased duration of time on land (Brasseur et al. 1996, Suryan and Harvey 1999). In terms of the health of the SFB's seal population, the long-term impacts of seals being forced to shift to nighttime haul-out site use are not yet known. However, these potential impacts are worth considering, particularly if such a shift results in changes in types of prey used by seals. Thompson et al. (1997) noted the physiological responses of harbor seals to changes in their diet composition, and stressed the need to consider such potential long-term effects on harbor seal populations.

In addition, Allen et al. (1984) postulated that abandonment of haul-out sites in Marin County, California, might result in overall population losses, if other traditional haul-out sites could not support additional seals, due to limitations on space and nearby food sources. Given the projected human population increase in the SFB area from 6.9 million in 2000 to 8 million in 2020<sup>17</sup>, the increased development and use of the SFB associated with this growth has the potential to significantly impact the SFB's harbor seal population. In the face of continuing urbanization, maintaining the integrity of harbor seal haul-out sites is important for protecting harbor seal populations.

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<sup>16</sup> Riseborough, R.W., D. Alcorn, S.G. Allen, V.C. Anderlini, L. Booren, R.L. DeLong, L.E. Fancher, R.E. Jones, M. McGinnis, T.T. Schmidt. 1980. Population biology of harbor seals in San Francisco Bay, California. National Technical Information Service, U.S. Department of Commerce, Springfield, VA, USA, 22161. Report Number MMC-76/19.

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with Incidental Harassment Authorizations (IHA) (fr23dc97-52 and fr14ja00-38) issued by the National Marine Fisheries Service (NMFS) to the California Department of Transportation (Caltrans). These IHA's are under the authority of Section 101 (a) (5) (D) of the Marine Mammal Protection Act (16 U.S.C. 1361 *et seq.*), and refer to monitoring of harbor seals during the seismic retrofit construction of the Richmond-San Rafael Bridge, San Francisco Bay, CA. Caltrans is providing all funding associated with this project. This work was approved by the SFSU Institutional Animal Care and Use Committee (IACUC) (#99-534).

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## SEASONAL DIETS OF WILD PIGS IN OAK WOODLANDS OF THE CENTRAL COAST REGION OF CALIFORNIA

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Wild pigs, *Sus scrofa*, an introduced species in California, are hypothesized to compete with native species for food and to consume some native vertebrates. To assess the potential for these impacts, we collected stomach contents of wild pigs over a 1-year period to evaluate seasonal and sex-related variation in diets of wild pigs in oak woodland habitats of the central coast region of California. Diets of the sexes were similar, but diets of wild pigs varied seasonally and related to acorn mast availability during the autumn. The proportion of animal tissue in diets increased concurrently with acorns, supporting earlier studies. Acorn consumption by wild pigs may impact oak regeneration as well as native vertebrates that consume acorns.

### INTRODUCTION

Wild pigs in California are hybrids of feral pigs first established during the 1800s and Eurasian wild boars, first introduced in 1925. In areas where they are not native, wild pigs are a conservation concern because their foraging activities impact a variety of plants and animals by consumption, competition, or disturbance (Laurance and Harrington 1997, de Nevers and Goatcher 1990, Howe et al. 1981). Concerns over the ecological effects of wild pigs in California have increased in recent years, as populations increased and expanded throughout oak woodland habitats (Waithman et al. 1999). Oak woodlands are a unique and diverse habitat providing watershed protection, public



recreation opportunities, commodity production for farmers and ranchers, and habitat and forage for over 300 wildlife species (Pavlik et al. 1992).

In California, wild pigs are hypothesized to compete with native species for acorn mast (Barrett 1982) and they may prey on some native vertebrates (de Nevers 1993). Rooting by wild pigs has been known to physically damage tree seedlings (de Nevers and Goatcher 1990, Becker 1985) and is hypothesized to negatively effect tree regeneration potential (Bruijnderink and Hazebroek 1996, Peart et al. 1994) and alter competitive relations in plant communities in ways that favor nonnative annual plants (Dyer and Rice 1999, Kotanen 1995). To assess these possibilities, we analyzed seasonal diets of wild pigs from oak woodland communities in the central coast range of Santa Clara County California. Like other ungulates (Main et al. 1996), adult male and adult female wild pigs do not closely associate except when mating (Ilse and Hellgren 1995). Thus, male and female wild pigs may consume different food associated with differences in habitat use and nutritional needs, so we also assessed potential sex differences in diets.

## METHODS

The study was conducted in northern Santa Clara County, California, on the west-facing slope of the Diablo Range on the Blue Oak Ranch (37°24.5'N, 121°44.2'W). The Blue Oak Ranch covers 1,330 ha with elevations ranging from 500 to 950 m. The study area supports several threatened plant communities, including valley oak *Quercus lobata* woodlands; blue oak *Q. douglasii* woodlands; and native perennial grasslands (Bainbridge and Kan<sup>1</sup> 1997).

Stomach contents of 53 wild pigs taken by rifle during 1999 were examined. Whole stomachs were immediately removed, allowed to cool, then frozen. In preparation for analysis, stomachs were thawed and sub-sampled by thoroughly mixing and then removing approximately 600 g of material. Each sub-sample represented 20 to 80 percent of the entire stomach contents. Samples were rinsed through a set of 3 consecutive sieves of decreasing mesh size (standard mesh sizes 35, 10, 5) to separate food items by size and to remove very fine particles that likely were unidentifiable (Korschgen 1962). Stomach contents were dried for 24 hours at 50°C; categorized as herbaceous vegetation, mast, bulbs and roots, animal remains, or unidentifiable debris; and weighed. All stomach samples contained small amounts of unidentifiable debris that were included when calculating dry weights of each food category, but omitted from statistical analyses. Dry weights were calculated for each food category. Vertebrate remains were identified to the lowest possible taxon by comparison with museum specimens. Diet frequency data were analyzed with a G-test (SYSTAT 8.0).

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<sup>1</sup> Bainbridge, S. and T. Kan. 1997. Botanical Survey of Blue Oak Ranch, Santa Clara County, California. Unpublished document on file at The Nature Conservancy Regional Office, San Francisco, California.



We used data from a companion study at a nearby state park (Henry Coe State Park) approximately 15 km south of The Blue Oak Ranch (Sweitzer and Van Vuren<sup>2</sup> 2001) to assess the availability of acorns for consumption by wild pigs in the region. As part of this companion study, surveys conducted during summer 1999 were used to locate and select 15 different category IV high-mast producing oak trees (Graves 1980) for monitoring total numbers of acorns on four 1 X 1 m acorn-monitoring plots beneath the canopy of each tree during fall 1999. Two of the four 1 X 1 m acorn-monitoring plots at each tree were inside of a 3 X 3 m pig proof fenced enclosure (experimental plots) and two were exposed to wild pig foraging (control plots). The fenced enclosures were used to assess the effect of wild pig foraging on acorn survival in the companion study (Sweitzer and Van Vuren<sup>2</sup> 2001). The 15 high-mast-producing oak trees used to monitor acorn availability included 7 blue oaks; 3 coast live oaks *Q. agrifolia*; 4 valley oaks; and 1 oregon oak *Q. garryana*. Beginning in mid September 1999, the total numbers of acorns on all acorn monitoring plots beneath each tree were counted at approximately 3-week intervals until mid December (acorns were returned to the plots after being counted). Data for all acorns located on experimental and control acorn monitoring plots were summed across all 15 trees on each count date to provide an index to the number of acorns available for wild pig consumption in the region during fall 1999.

## RESULTS

We collected a total of 53 wild pigs during 1999. Initial analyses did not demonstrate any statistical difference in the diets of male and female wild pigs ( $G = 2.77$ ,  $df = 1$ ,  $P = 0.5$ ), so data were pooled for seasonal analyses. There was significant seasonal variation in the diets of wild pigs during 1999 (Table 1;  $G = 40.3$ ,  $df = 9$ ,  $P < 0.01$ ). Herbaceous vegetation predominated in diets of wild pigs in all seasons except autumn, when the proportions of acorns and animal material increased dramatically (Fig. 1). Bulbs and roots constituted a very small proportion of the diet of wild pigs year-round. Animal material was detected in the diet during the summer and autumn, but not during winter and spring (Fig. 1). Of the 8 stomachs with animal material, 2 contained voles, *Microtus* sp.; 1 contained mule deer, *Odocoileus hemionus*; and 5 contained remains of California ground squirrels, *Spermophilus beecheyi*. The stomach containing deer remains was from a wild pig that was shot while scavenging a deer carcass. One of the wild pigs with California ground squirrel remains in its stomach (a nearly intact adult squirrel) was observed standing motionless for over 20 minutes as it intently waited above a ground squirrel burrow immediately before being shot.

Data on availability of acorns for wildlife were recorded during autumn 1999 at Henry

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<sup>2</sup> Sweitzer, R.A. and D. Van Vuren. 2001. *In review*. Ecological effects of wild pigs in oak woodland ecosystems in northern California. Proceedings of the 5th Symposium on California's Oak Woodlands. Integrated Hardwood and Range Management Program, University of California, Berkeley, California.



Table 1. Frequency of occurrence (%) of food items by season and by sex (M=male, F=female) for pigs. Numbers of pigs for each period are in parentheses.

	Winter		Spring		Summer		Autumn	
	M (4)	F (9)	M (6)	F (12)	M (6)	F (4)	M (9)	F (3)
Herbaceous	100	100	66.6	81.8	31.6	30.7	34.8	0
Acorn Mast	0	0	0	0	31.6	23.1	39.1	40
Bulbs & Roots	0	0	16.7	9.1	26.3	23.1	8.7	20
Animal Material	0	0	16.7	9.1	10.5	23.1	17.4	40

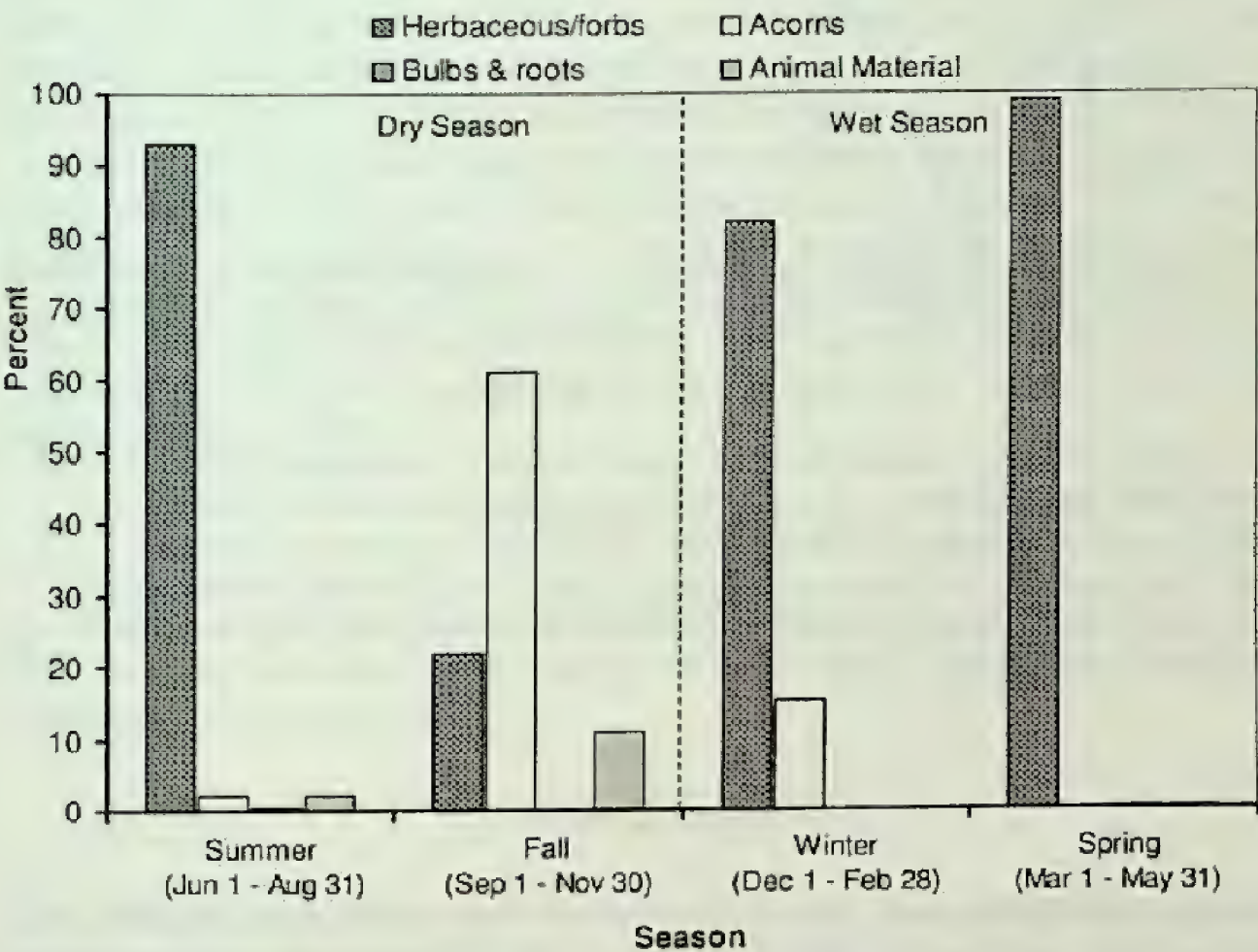


Figure 1. Seasonal variation ( $G = 40.3$ ,  $df = 9$ ,  $P < 0.01$ ) in the diets of 53 wild pigs from the Blue Oak Ranch, Santa Clara County.

Coe State Park approximately 15 km south of the Blue Oak Ranch (R. Sweitzer, University of North Dakota, unpublished data). A visual comparison of wild pig diets and acorn availability data suggested that the diets closely tracked availability of acorns during the autumn and winter periods of 1999 (Fig. 2).



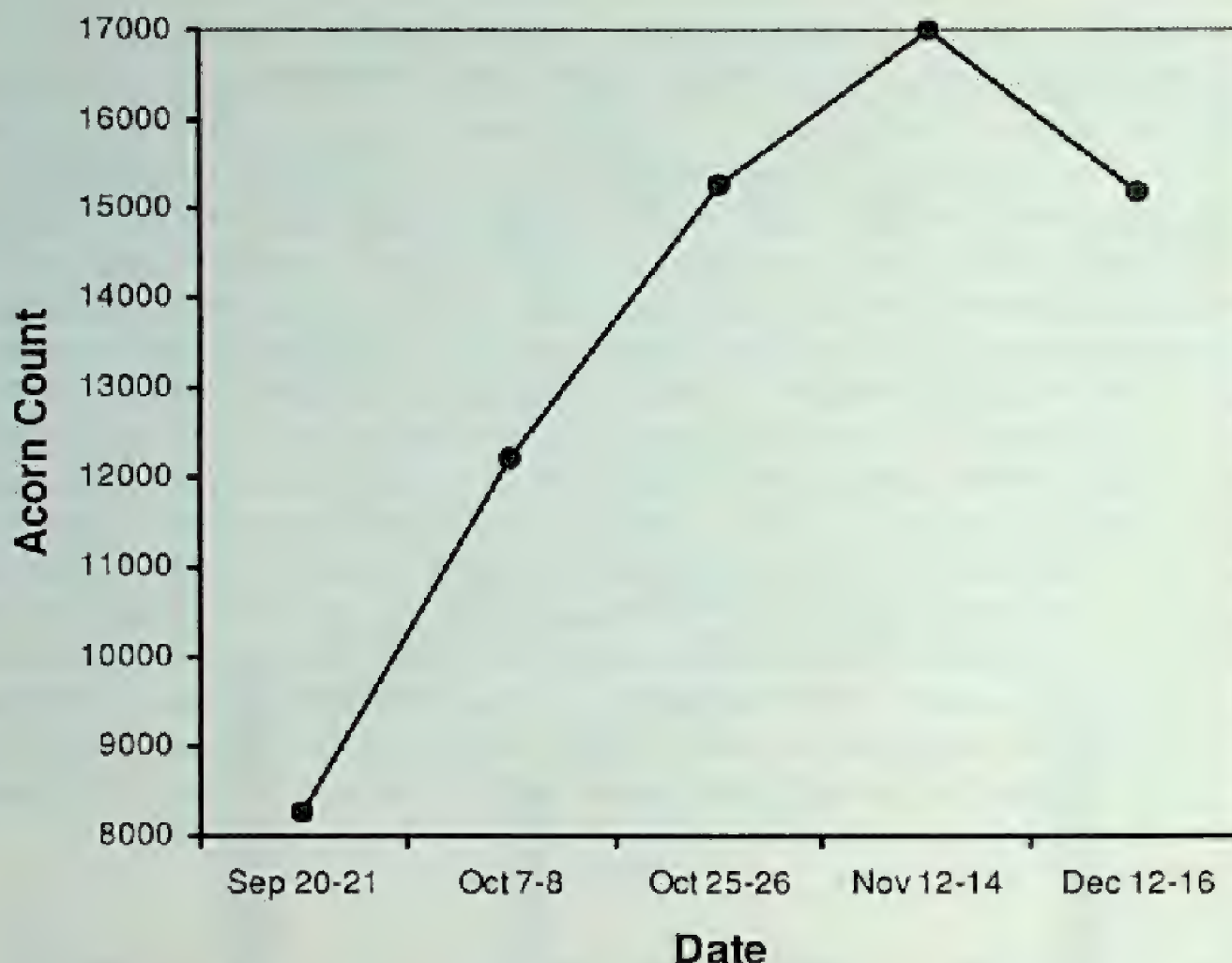


Figure 2. Data on acorn availability from plots beneath 15 category IV high-mast-producing oak trees at Henry Coe State Park, Santa Clara County that were periodically sampled during autumn 1999. Data for all acorns located on experimental and control acorn-monitoring plots were summed across all 15 trees on each count date to provide an index to the number of acorns available for wild pig consumption.

## DISCUSSION

We detected no difference in the diets of male and female wild pigs, suggesting that differences in social behavior between males and females is not necessarily reflected in their foraging behavior. Except for autumn, diets of wild pigs were quite similar among seasons. The difference between autumn and other times of the year was related almost entirely to the increased availability of acorn mast during the autumn period (Fig. 1). Herbaceous plants and forbs were the primary constituents of the diets of wild pigs in all periods except when acorns predominated. Increased consumption of acorns by wild pigs appeared to closely track the increased availability of acorns during autumn. These results were similar to other studies of food habits of wild pigs in California and other parts of the United States where acorn or beech mast becomes seasonally available (Belden and Frankenberger 1990, Schauss et al. 1990, Baber and Coblenz 1987).



During autumn, acorns were the primary dietary component (Fig. 1). Acorns contain proportionally low levels of crude protein in relation to total energy (Barrett 1978), and it has been suggested that wild pigs must compensate by increasing their intake of protein when consuming large quantities of acorns (Belden and Frankenger 1990). Animal tissue is a better source of protein than plant material (Robbins 1993), and the wild pigs sampled in this study may have increased their consumption of vertebrates and invertebrates during the autumn (Fig. 1) to compensate for the low protein content of acorns. The absence of animal matter during winter may be a result of our sampling procedure. These stomachs were observed to contain earthworms (*Lumbricus* sp.) upon collection but were not found later during analysis and may have been digested between the time of collection and analysis.

Wild pigs may negatively influence California's oak woodland ecosystems in a variety of ways (Sweitzer 1998). Our data indicate that wild pigs consume primarily acorns during the autumn. This may directly impact regeneration of oaks and secondarily other animals that consume acorns. Moreover, our data indicate that wild pigs also consume native vertebrates and the occurrence of California ground squirrels in almost 10% of stomachs suggested active predation, since carcasses of burrow-dwelling squirrels are seldom available above ground (VanVuren 2001). Previous studies have suggested that animal tissues in the stomachs of wild pigs were derived from scavenging (Baber and Coblenz 1987), but we suggest that scavenging is not as behaviorally consistent as is active predation with respect to small native vertebrates, a finding that may be important if the target prey are of conservation concern (McFarland et al. 1974).

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## GROWTH OF AMERICAN RIVER FALL-RUN CHINOOK SALMON IN CALIFORNIA'S CENTRAL VALLEY: TEMPERATURE AND RATION EFFECTS

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### ABSTRACT

Food consumption and growth rates of juvenile American River fall-run chinook salmon (*Oncorhynchus tshawytscha*) were measured at temperatures of 11, 15, and 19°C and ration levels of 100 and 25% satiation. Increasing temperature had a positive, significant effect on the growth and food consumption rates of salmon receiving the full ration. Salmon receiving the 25% ration had negative growth rates that were temperature independent. Growth rates of American River fall-run chinook are similar to those for more northern strains; a slight indication of greater adaptation to warmer water temperatures was noted for the thermal range tested.

### INTRODUCTION

Chinook salmon, *Oncorhynchus tshawytscha*, that spawn in California's Central Valley (primarily in the mainstem Sacramento River and its tributaries) are members of the southernmost extant populations (Moyle 2002). Within this basin, there are at least four distinct salmon races or strains, including the Sacramento River winter, spring, fall, and late-fall runs (Moyle 2002). All Central Valley runs have been impacted to varying degrees by the effects of water development, habitat degradation, and over-harvest. The severity of these declines has led to the protection of the winter and spring runs under state and federal endangered species laws (Moyle 2002); recovery efforts, ranging from captive breeding programs to the development of management plans, have also been initiated.

The outcomes of the various recovery efforts hinge on a number of factors, including the availability of accurate data on the effects of biotic and abiotic factors on the survival of vulnerable life-stages, particularly larval and juvenile salmon (Kope and Botsford 1990). To date, however, few studies on the effects of factors, such as

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water temperature and ration level, have been published for Central Valley races. Castleberry et al. (1993)<sup>2</sup> evaluated the relationships between river conditions and growth rate, condition, and physiological performance of wild-caught juvenile chinook salmon and steelhead (*O. mykiss*) from the American River. The feeding and thermal history of these fish was not well known, but temperatures in the 15 to 17°C range appeared to be conducive to high growth rates. Marine (1997)<sup>3</sup> reared juvenile Sacramento River fall-run chinook salmon under low (13 to 16°C), moderate (17 to 20°C) and high (21 to 24°C) temperature regimes. Maximal growth rates of 3.3 percent weight per day (% weight/day) were observed in salmon reared at 17-20°C, with lower growth rates in salmon reared at 13-16°C and 21-24°C (Marine 1997)<sup>2</sup>. More extensive studies have been published for a number of chinook salmon races from more northern latitudes. Brett et al. (1982) reported that Big Qualicum River (BC, Canada) and Nechako River (BC, Canada) salmon fed maximal rations grew fastest at 20.5 and 18.9°C, respectively. Shelbourn et al. (1995) reported a reduction in growth rates as water temperatures declined for Nechako River salmon. Latitudinal differences in physiological performance (Kreiberg 1989)<sup>4</sup>, behavior (Taylor and Foote 1991), and life-history strategies (Healey 1994) have been reported for other *Oncorhynchus* species. Because Central Valley salmon reside at the southernmost limit of their distribution, it is not unreasonable to expect appropriate responses to local environmental conditions, perhaps in terms of superior warm-water adaptation.

The purpose of this study was to evaluate the effects of temperature (11, 15, and 19°C) and ration level (100 and 25% of satiation) on the growth of American River fall-run chinook salmon. Our objectives were 1) to collect and publish baseline data on the growth of fall-run salmon for use in recovery efforts and; 2) to compare fall-run data with those published for salmon from northern races to see if significant differences in temperature responses exist. We predicted that American River fall-run chinook would show similar temperature responses to more northern strains (e.g., higher growth and food consumption as temperatures approached 19°C), but with comparatively higher growth rates than northern strains tested at similar temperatures because of a higher food conversion efficiency.

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<sup>2</sup> Castleberry, D.T., J.J. Cech, Jr., M.K. Saiki, and B.A. Martin. Growth, condition, and physiological performance of juvenile salmonids from the lower American River: February through June 1992. Oakland, California: U.S. Fish and Wildlife Service, 1993.

<sup>3</sup> Marine, K.M. 1997. Effects of elevated water temperature on some aspects of the physiological and ecological performance of juvenile chinook salmon (*Oncorhynchus tshawytscha*): implications for management of California's Central Valley salmon stocks. Masters Thesis. University of California, Davis.

<sup>4</sup> Kreiberg, H. 1989. Salmonid growth under different environmental conditions: toward a general growth model for chinook salmon. Proceedings of the Canada-Norway Finfish Aquaculture Workshop, Biological Station, St. Andrews, New Brunswick.





Figure 1. Location of the Lower American River in California's Central Valley.

## METHODS

American River fall-run chinook salmon were hatched and reared at the Nimbus Salmon and Steelhead Hatchery, which is owned by the U.S Bureau of Reclamation and operated by the California Department of Fish and Game. Fish ( $n = 720$ ; mean weight: 1.7 g; mean total length: 60.4 mm) were transferred to the University of California, Davis, in late April 1998 and acclimated to air-equilibrated well water at 11, 15, and 19°C at 1°C/d. Salmon were stocked in 110-L round fiberglass tanks (four replicate tanks per temperature  $\times$  ration treatment) at a density of 30 fish per tank. The indoor tanks received natural light through translucent roof panels and artificial lighting set to the natural photoperiod (latitude 38°55' N; May to July). Tanks received a constant flow (4 L/min)



of 11, 15, or 19°C water. Water temperatures were monitored and maintained by a microprocessor-controlled mixing valve. Current velocities were adjusted using angled spray bars to one body length per second and flow direction was reversed every 5 days to uniformly exercise the fish. Mean well-water characteristics during the experiments were: total dissolved solids 390 mg/L, total suspended solids < 5.0 mg/L, total alkalinity 300 mg/L, pH 7.8, and hardness 320 mg/L. Dissolved oxygen concentrations in the flow-through experimental tanks, which also incorporated continuous aeration, were never below 90% air-saturation; weekly tests for dissolved ammonia detected none (0.1 mg/L detection limit).

Chinook salmon were fed Rangen 1.6 mm semi-moist salmon pellets. Fish were fed a full satiation ration (100% satiation) or a reduced ration (25% of satiation). The reduced rations were calculated using:

$$\text{Reduced ration} = \frac{\sum FC_{d-1}}{\sum W_f} \times W_r \times k \quad (1)$$

where  $\sum FC_{d-1}$  is the total amount of food consumed (g) by all the full-ration tanks at temperature  $T$  the previous day,  $W_f$  is the sum of the biomass (g) of the 4 full-ration tanks at temperature  $T$  from the previous weighing,  $W_r$  is the biomass (g) of the particular reduced-ration tank from the previous weighing, and  $k$  is the reduction coefficient (0.25). The amount of food consumed was calculated by subtracting the number of pellets remaining in the tanks from the estimated number of pellets fed, based on a mean pellet weight of  $0.005 \pm 0.0003$  g. The amount of food consumed was quantified after each feeding by subtracting the wet weight of the uneaten pellets from the wet weight of the food given. Feed dry weights were calculated by multiplying the wet weights by the percent dry matter determined from oven-dried feed samples (10% moisture). Mean consumption rate ( $C$ ) in percent body weight of food consumed per day was calculated for each tank (Wurtsbaugh and Davis 1977) using:

$$C = \frac{C_i}{0.5 \times (W_1 + W_2) \times t} \times 100 \quad (2)$$

where  $W_1$  is the initial estimated dry weight of a group of fish,  $W_2$  is the final dry weight of the group of fish,  $t$  is the duration of the experiment in days (30 days),  $C_i$  = estimated dry weight of food consumed. Fish dry weights were estimated by multiplying the total wet weight of the fish in each tank by the mean dry weights determined by oven-drying a subsample of 5 fish per treatment per sampling date at 60°C for 7 days.

Growth rates were determined on a per tank basis. All fish were weighed and measured on day 0, 10, 20, and 30. Fish were fasted for 24 h prior to weighing, anesthetized (50 ppm MS-222; 3‰ NaCl; 0.1‰ NaHCO<sub>3</sub>), weighed to the nearest 0.1 g on a calibrated electronic balance and standard, fork, and total lengths measured to the nearest mm. Mean growth rates ( $G$ , in %weight/day) were calculated (Wurtsbaugh and Davis 1977) using:

$$G = \frac{W_2 - W_1}{0.5 \times (W_1 + W_2) \times t} \times 100 \quad (3)$$



In order to facilitate comparison with literature values, we also calculated instantaneous or "specific" growth rates (*SGR*; Busacker et al. 1990), using:

$$SGR = \frac{\ln W_2 - W_1}{(t_2 - t_1)} \quad (4)$$

Gross food conversion efficiencies (*GCE*, %) were calculated for each tank using:

$$GCE = \frac{W_2 - W_1}{\sum_{30} C_i} \times 100 \quad (5)$$

where  $W_1$ ,  $W_2$  and  $C_i$  were as above. Mean initial and final weights for each treatment were compared using Student *t*-tests. Differences among treatment mean *C* were tested using one-way ANOVA, with an  $\alpha$  level of 0.05. The responses of *G* and *GCE* to the effects of temperature, ration level, and their interaction were evaluated using two-way ANOVA, with  $\alpha$  levels of 0.05. Multiple pairwise comparisons were made using the Tukey HSD method (SAS 2000) at an  $\alpha$  level of 0.05, but experiment-wise alpha levels were not used.

## RESULTS

Salmon food consumption rates, growth rates, and gross conversion efficiencies were affected by temperature and ration level. Food consumption rates increased significantly with temperature (ANOVA; all  $P < 0.01$ ; Table 1, 2). Both growth rates measures showed significant ( $F = 348.76$ ;  $df = 5$ ;  $P < 0.01$  for *G*; and,  $F = 359.94$ ;  $df = 5$ ;  $P < 0.01$  for *SGR*) temperature, ration, and interaction effects, whereas conversion efficiencies only showed a significant ration effect ( $F = 120.12$ ;  $df = 1$ ;  $P < 0.01$ ; Table 1, 2). Salmon receiving the 25% ration did not show increased growth rates as temperature increased; the increase in consumption rates results from the dependence of the ration size on the corresponding 100% ration at that temperature. Gross conversion efficiencies for salmon receiving the 100% ration did not differ significantly with temperature, with an overall mean of 27%. Gross conversion efficiencies for reduced-ration salmon were all negative, with an overall mean of -10.2%.

## DISCUSSION

Our prediction that American River fall-run chinook food consumption and growth rates would increase as temperature increased over the 11 - 19°C range is supported by our findings. Food consumption and growth rates for salmon receiving 100% rations increased significantly with each increase in temperature from 11 to 15 to 19°C. Gross conversion efficiency showed a similar trend, but differences among temperatures were not statistically significant. Our results indicate that fall-run salmon can achieve high growth rates when favorable food and environmental conditions are present. If food



Table 1. Effects of temperature on the food consumption rates (*C*), growth rates (*G*), specific growth rates (*SGR*) and gross conversion efficiencies (*GCE*) of American River fall-run chinook salmon fed to 25% of satiation. Abbreviation for weight is "wt." and day is "d." Values are means  $\pm$  SE. Significant differences ( $P < 0.01$ ) are indicated by \*\*.

Temperature	n	<i>C</i> (% body wt./d)	<i>G</i> (% body wt./d)	<i>SGR</i> (% wt./d)	<i>GCE</i> (%)
11°	4	3.72 $\pm$ 0.04	-0.28 $\pm$ 0.08	-0.28 $\pm$ 0.08	-7.3 $\pm$ 2.0
15°	4	5.49 $\pm$ 0.06	-0.75 $\pm$ 0.14	-0.75 $\pm$ 0.14	-13.6 $\pm$ 2.5
19°	4	5.65 $\pm$ 0.13 **	-0.53 $\pm$ 0.18	-0.54 $\pm$ 0.18	-9.6 $\pm$ 3.2

Table 2. Effects of temperature on the food consumption rates (*C*), growth rates (*G*), specific growth rates (*SGR*) and gross conversion efficiencies (*GCE*) of American River fall-run chinook salmon fed satiation rations. Abbreviation for weight is "wt" and day is "d". Values are means  $\pm$  SE. Significant differences ( $P < 0.01$ ) are indicated by \*\*.

Temperature	n	<i>C</i> (% body wt./d)	<i>G</i> (% body wt./d)	<i>SGR</i> (% wt./d)	<i>GCE</i> (%)
11°	4	11.20 $\pm$ 0.26 **	2.68 $\pm$ 0.16 **	2.84 $\pm$ 0.20**	23.9 $\pm$ 1.4
15°	4	13.49 $\pm$ 0.26 **	3.60 $\pm$ 0.06 **	4.02 $\pm$ 0.09**	26.7 $\pm$ 0.4
19°	4	15.02 $\pm$ 0.53 **	4.38 $\pm$ 0.05 **	5.25 $\pm$ 0.10**	29.3 $\pm$ 1.2

resources are severely limited, as simulated by our 25% ration treatments, juvenile salmon are incapable of maintaining condition over the 11 - 19°C range.

American River fall-run and chinook salmon races further north respond similarly to increases in water temperature (Table 3). Fall-run fish used in this study performed similarly to both Sacramento River and British Columbia strains (Table 3). The observed differences are likely due to unequal fish size and experiment duration. Smaller fish tend to have higher growth rates than larger fish (Elliott 1976); short-term growth rates are typically higher than those measured over longer intervals. Growth rates for American River fall-run salmon tested at 19°C were the highest reported for any chinook race. The different results may be partially explained by the different initial weights and experiment duration, but the magnitude of the difference (1.3 - 2.0 % wt./d) suggests that the American River fall-run salmon are slightly better adapted to growth at 19°C. We observed maximal growth rates at 19°C, supporting earlier findings by Brett et al. (1982) and Marine (1997)<sup>2</sup>. It is important to note that these maximal growth rates only occurred when the fish were fed satiation rations under optimal environmental conditions. Should rations be reduced to some level below 100% satiation, as would be expected in the wild (Petrusso and Hayes 2001), then optimal growth temperatures would be somewhat lower, as has been shown in chinook salmon and other salmonids (Elliott 1975, Elliott 1976, Brett et al. 1982).

One interesting result noted in the 25% ration treatments was the change in relative size distribution over the course of the experiment. The distribution of initial weights in the 25% treatments was normal, but following the 30-d experiment, there were one



Table 3. Comparison of growth rates ( $G$ ) of California Central Valley chinook salmon with salmon from more northern latitudes. Sources of data are as follows: 1. Brett et al. (1982); 2. This study; 3. Clarke and Shelbourn (1985); 4. Marine (1997)<sup>2</sup> and; 5. Shelbourn et al. (1995). Abbreviation for weight is "wt." and day is "d".

Temp. (°C)	Strain	Initial weight (g)	Duration (days)	G (% wt./d)	Source
10.3	Nechako R.	2.9	N/A	1.4	5
11	American R.	1.7	30	2.7	2
14	Big Qualicum R.	3.4	28	3	1
15	American R.	1.7	30	3.6	2
16	Nechako R.	2.3	28	3.1	1
16	Big Qualicum R.	3.3	28	2.9	1
16	Big Qualicum R.	0.6	90	3.7	3
19	Nechako R.	2.3	28	3.1	1
19	Big Qualicum R.	3.3	28	3	1
19	American R.	1.7	30	4.4	2
13 – 16	Sacramento R.	0.8	105	3.1	4
17 – 20	Sacramento R.	0.8	105	3.3	4
21 – 24	Sacramento R.	0.9	105	2.9	4

to two large fish in each tank, while the remainder formed a regular weight distribution (Fig. 2). A dominance hierarchy was evident. Hierarchies of this type have been widely documented in both laboratory and field studies (Wagner et al. 1996, McMichael and Pearsons 1998) and implies that if food resources in Central Valley rivers become limited, then increasing salmon density through hatchery releases could negatively impact the growth of most salmon present, though a small group of dominant individuals may experience high growth rates.

In the case of salmon receiving satiation rations, initial and final weight distributions are similar (Fig. 3). As we noted with the reduced-ration salmon, there were typically 1 or 2 salmon per tank that were substantially larger than the rest. Unlike the 25% ration fish, however, these fish did not have as severe an effect on the growth rates of other fish in their tank because rations were unlimited.

American River fall-run chinook salmon appear well-adapted to conditions in the American River. Our study demonstrated that temperatures up to 19°C pose no problem for these fish, provided that food is abundant and environmental conditions are optimal. American River salmon respond to temperature in a manner similar to other Central Valley and northern races; the American River fish appear to be slightly better adapted to warm temperatures. If current American River management practices with respect to water temperature are maintained, conditions should not preclude the continued rearing of juvenile chinook salmon.

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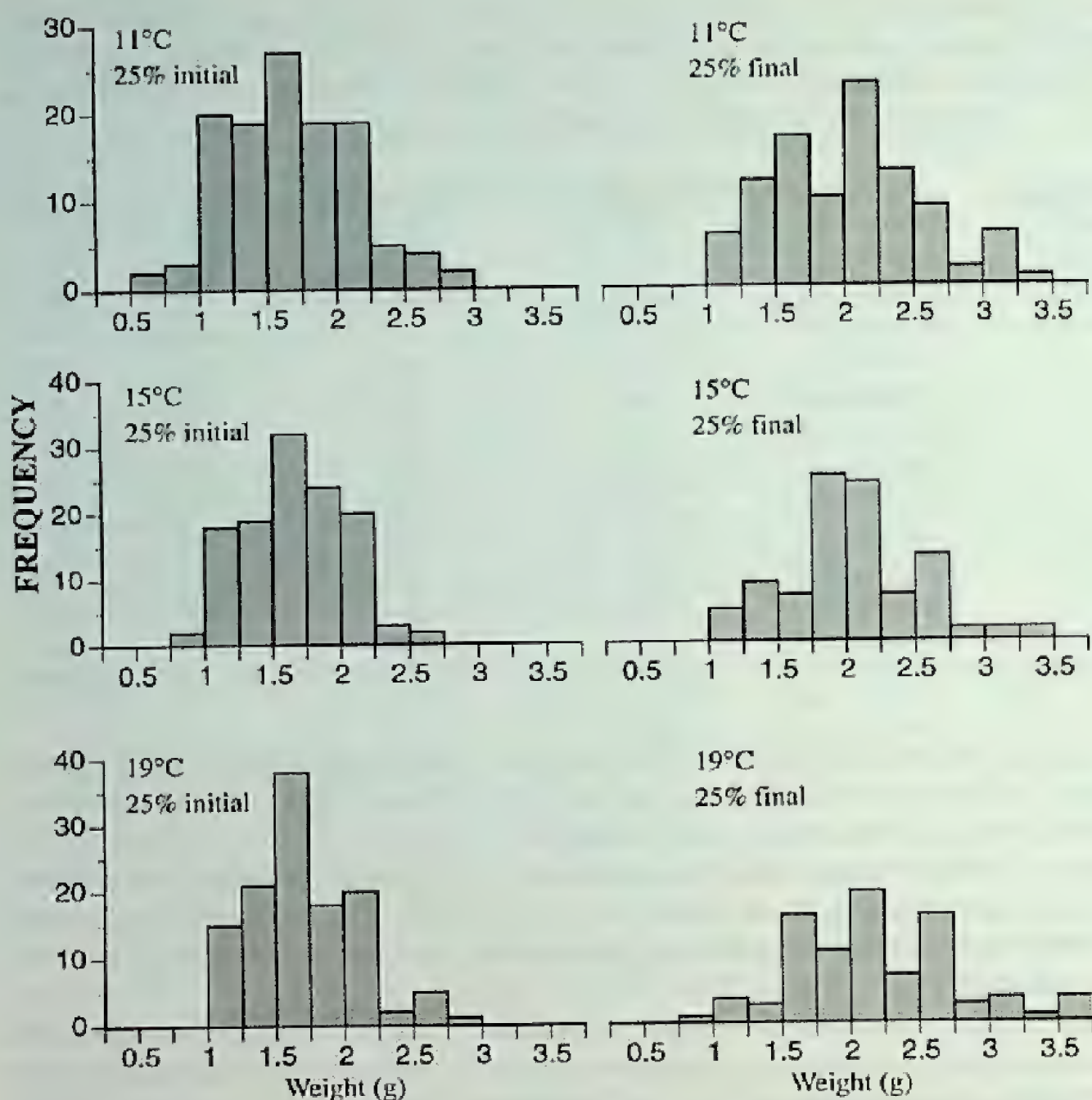


Figure 2. Distribution of initial and final weights (g) of American River fall-run chinook salmon fed 25% satiation rations.

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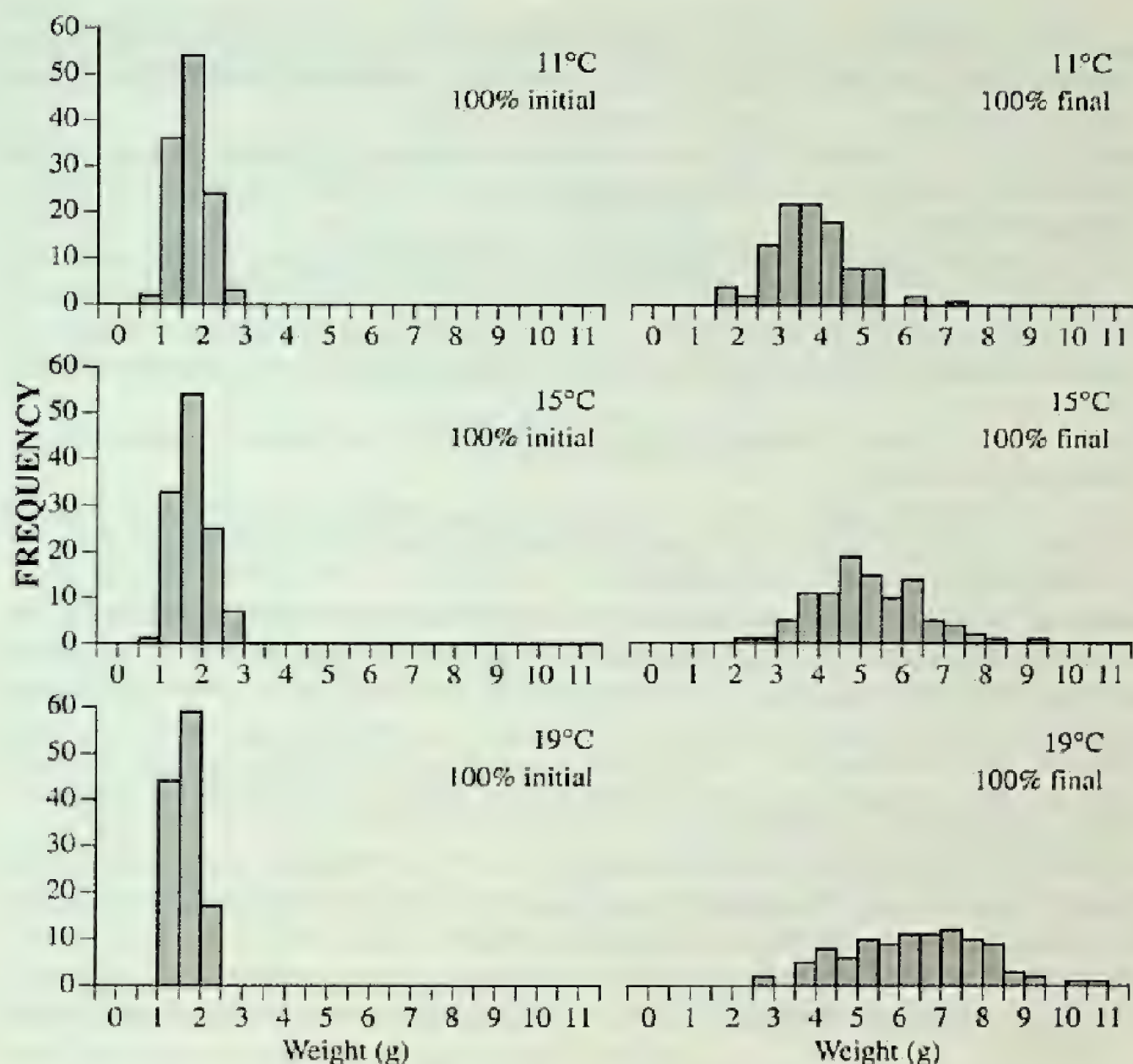


Figure 3. Distribution of initial and final weights (g) of American River fall-run chinook salmon fed satiation (100%) rations.

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## RECORD OF THE SHOULDERSPOT GRENADIER, *CAELORINCHUS SCAPHOPSIS*, FROM NORTHERN CALIFORNIA, U.S.A.

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The shoulderspot grenadier, *Caelorinchus scaphopsis* (Gilbert 1890), is a member of a large genus with more than 100 species (Iwamoto and Williams 1999), most of which are temperate or tropical in distribution. The shoulderspot grenadier is the only member of the genus known from the eastern North Pacific Ocean north of Point Conception, California (Iwamoto and Stein 1974, Iwamoto 1978, Cohen et al. 1990). It is reportedly abundant in the Gulf of California and along the outer coast of Baja California at depths of 183 to 296 m along the upper continental slope.

On October 23, 2000 a shoulderspot grenadier was collected from northern California during the Alaska Fisheries Science Center annual groundfish survey of the upper continental slope (depths from 183 to 1,280 m) conducted off California, Oregon, and Washington (Lauth 2001<sup>1</sup>). The specimen (UW 040281, 1, (60.3 mm HL, 242 mm TL), 237 m depth, 7.5°C bottom temperature, 41°14'50"N, 124°24'6"W) was collected using a bottom trawl. The northern California specimen extends the northern range of the shoulderspot grenadier by approximately 650 km.

The specimen collected at 41°N (Fig. 1) agrees with the original and later descriptions of the shoulderspot grenadiers reported from south of Point Conception, California (Gilbert 1890, Iwamoto and Stein 1974, Iwamoto 1978, Cohen et al. 1990).

Description: An adult specimen with a pronounced snout and sharp stout scales laterally; color brownish dorsally and bluish black ventrally; darkish pectoral, pelvic, and dorsal fins and gill cavity; snout and underside of mouth lighter; anus removed anteriorly from the first anal fin by several scale rows; single black naked fossa slightly anterior of the pelvic fins; the second dorsal spine on the first dorsal fin smooth; underside of jaw, ventral margins on suborbital and mandible naked; adherent scales with pronounced spinule rows; 80.1 mm pre-anal fin length, 242.0 mm total length; 60.3 mm head length, 20.6 mm orbit width, 16.5 mm upper jaw length, 1<sup>st</sup> dorsal II, 8; pectoral

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<sup>1</sup>Lauth, R.R. 2001. The 2000 Pacific west coast upper continental slope trawl survey groundfish resources off Washington and Oregon: Estimates of distribution, abundance, and length composition. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-AFSC-120.



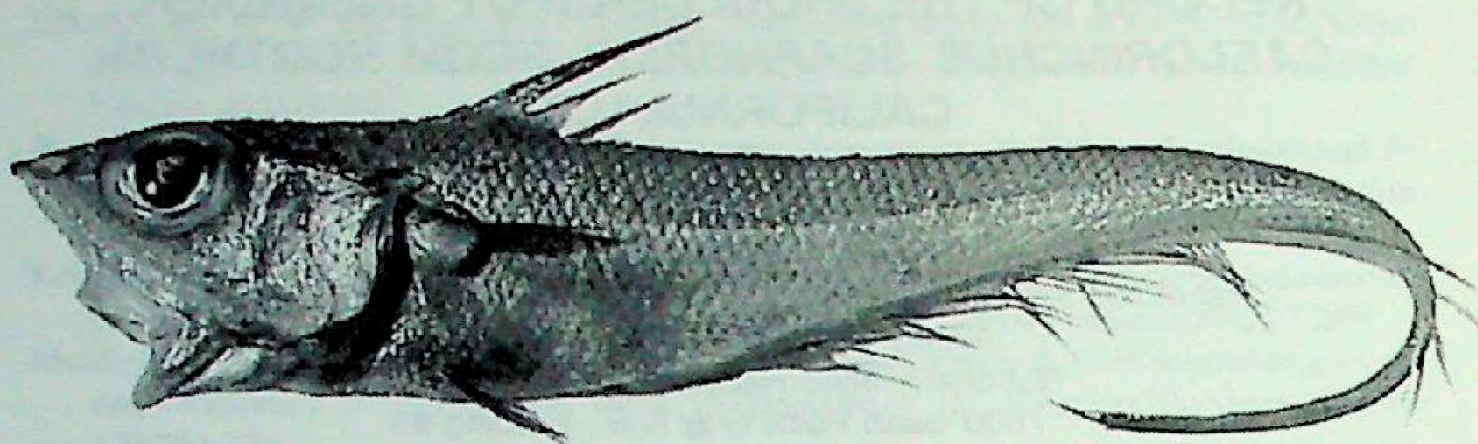


Figure 1. The shoulderspots grenadier, *Caelorinchus scaphopsis* collected from 41° N off northern California in October 2000.

117; 4.5 scales from mid-first dorsal fin to lateral line.

The shoulderspots grenadier co-occurs with at least eight other macrourid species along the California coast but is distinct from all others by the combination of heavily scaled suborbital ridge and pronounced snout, large naked fossa slightly anterior to pelvic fins, and 2<sup>nd</sup> spinous dorsal ray smooth (Iwamoto and Stein 1974).

Other specimens recorded by the Alaska Fisheries Science Center's groundfish surveys north of Point Conception, California suggests the shoulderspots grenadier occurs to 41°N and should be included as part of the temperate North Pacific fish fauna.

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